Control ENGINEERING

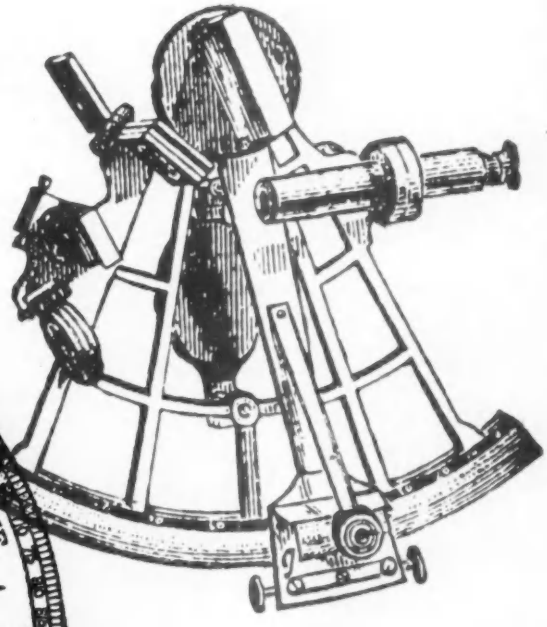
INSTRUMENTATION AND CONTROL SYSTEMS

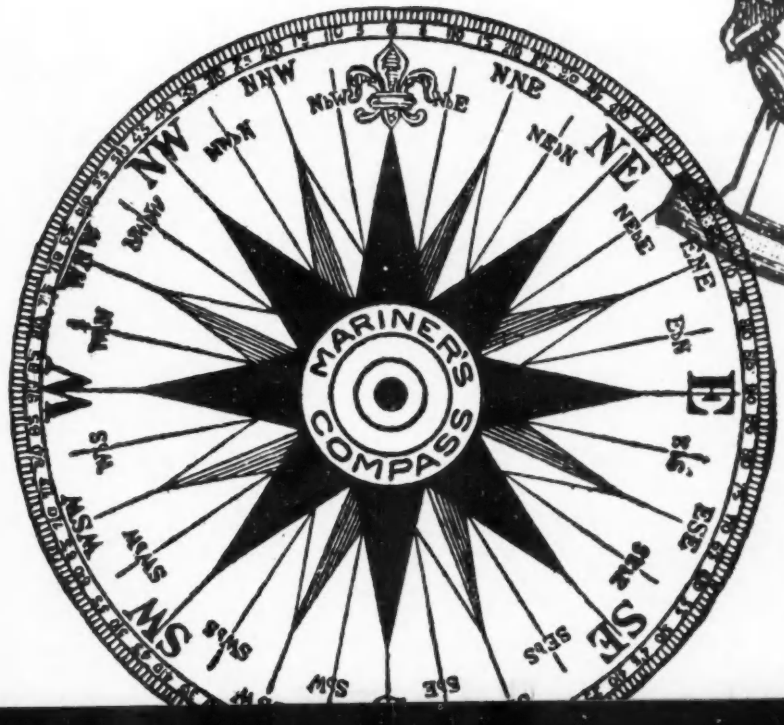
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AUGUST 1960





Special Report on GUIDANCE SYSTEMS





Also in this issue

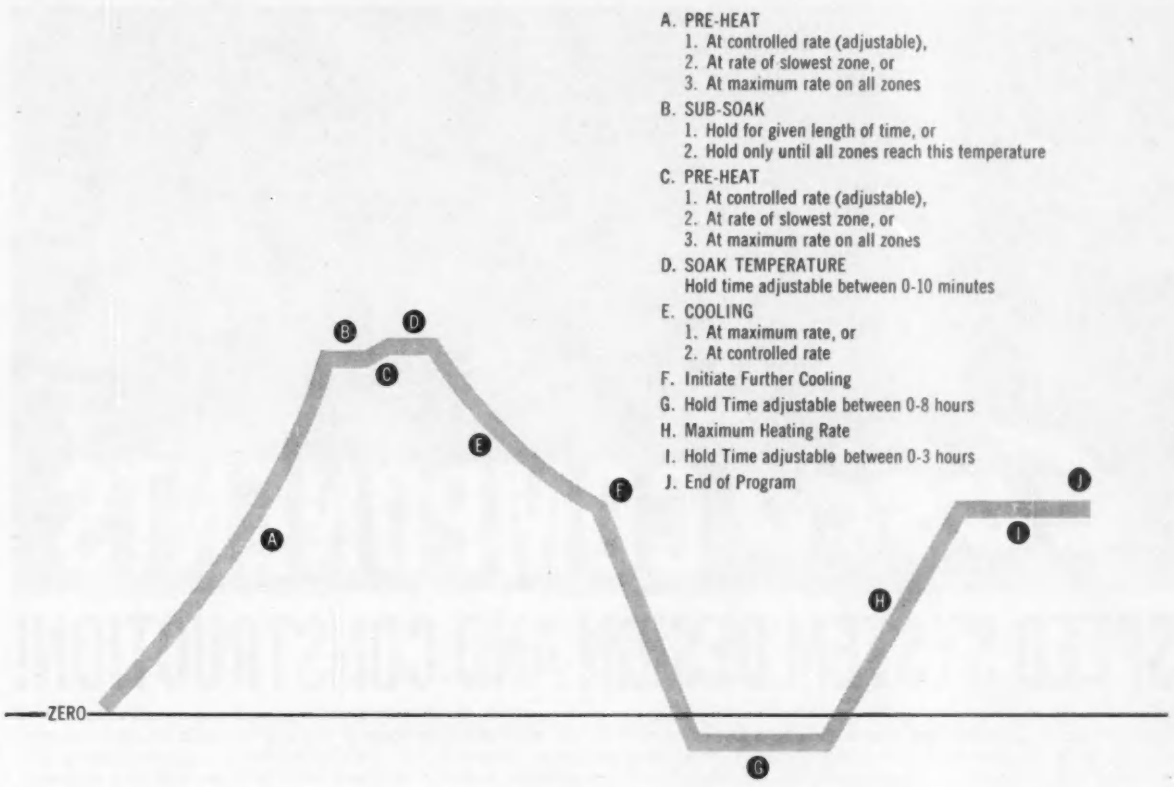
Time Sharing Positioning Drives
Specifying Analyzer Sample Lines
Examining the Adaptive Principle



Responding like the practiced reflexes of a deepwater sailor, shipboard weapons depend on sea legs provided by Librascope computers...attack directors, torpedo and missile angle solvers, weapons control computers, attack plotters, depth plotters, position keepers, target motion analyzers, stabilization computers, roll and pitch computers. Since 1940 Librascope computers have earned a seaworthy reputation serving aboard ships of the line, directing systems that are rugged, reliable and right. For career opportunities write to John Schmidt, Engineering Employment, Librascope Division. 808 Western Avenue, Glendale, California. **Librascope division, General Precision, Inc.**



CIRCLE 211 ON READER SERVICE CARD



When temperature uniformity is a must... reproduce your heat-treating cycles with L&N's new master-slave program control

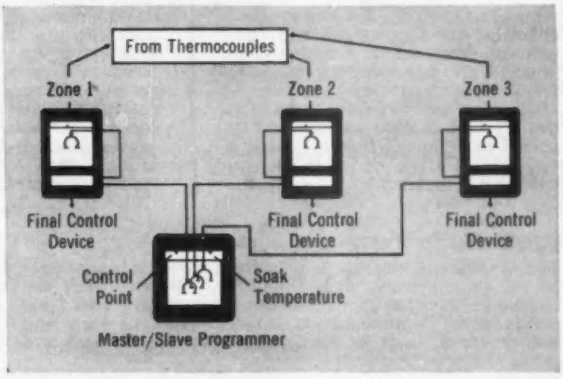
Designed for applications where temperature uniformity is of prime importance, L&N's new master-slave program control system has the flexibility to take your product—with minimum temperature gradient—through various heating and cooling cycles. It is currently being used in brazing stainless steel honeycomb panels for supersonic aircraft and missiles.

You can use this system on either batch or continuous furnaces . . . can control from either work or furnace temperatures. Heating cycles may be at a fixed rate, or at the rate determined by the slowest or fastest heating zone. As many as twenty-four zones may be automatically controlled by one master-slave programmer.

This master-slave system is available with 3-action P.A.T. control for fuel-fired furnaces; with 3-action C.A.T. control for continuous, stepless regulation of input to electric heaters or blankets; or with D.A.T. control for either electric or fuel-fired furnaces.

The system includes Speedomax® H controllers with appropriate couples and control devices for each zone; and a master-slave programmer for automatically and continuously adjusting control-point for each zone.

If your process can benefit from precisely controlled heating and cooling, you may be surprised to learn how large a return you can get by modernizing with this quality instrumentation. For details, call your nearest L&N office, or write us at 4918 Stenton Ave., Phila. 44, Pa. Ask for Process Data Sheet 660(2).



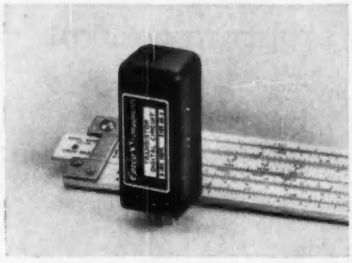
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Pioneers in Precision



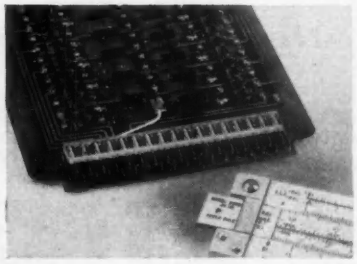
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Digital circuitry and control instrumentation is easier, quicker, surer with Epsco Components. The line is the broadest in the industry, answering more of your circuitry needs. It includes Transistor Digital Circuits — plug-in modules or printed circuit cards — and Magnetic Components — logic elements, shift register assemblies, and buffers. All types are electronically compatible, to simplify system design and construction. They are ideal as design tools in blocking out logic circuitry and prototype assembly. Epsco's quality control program assures their reliability. All TDC Modules and Cards are supplied with individual connectors. Their low cost and immediate availability from inventory are assured by Epsco's volume production.



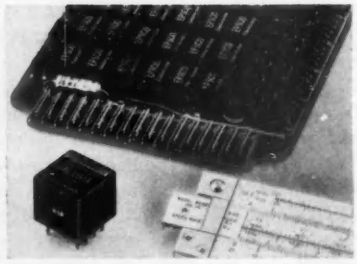
TDC Miniaturized Plug-in Modules

Clamped saturating logic circuitry, encapsulated for ruggedness and compactness, designed for wide tolerance, low noise. Temperature ranges —55°C. to +71°C. Frequencies in excess of 1 MC. Most economical approach to small system design, military and industrial equipment. (Now available — new Module Cage for high density packaging in systems.)



TDC Printed Circuit Cards

Complementing plug-in line, with identical circuitry. System-designed with wide loading tolerances and high noise thresholds, providing high packing density and cooling efficiency. Test points and visual indicators speed testing and servicing. Proven in military, general purpose and commercial applications. (Now available — Card Cage for optimum utilization of this line.)



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Logic elements and Shift Register Assemblies for high density, low cost, information storage, completely compatible with transistor logic circuitry. Ruggedized performance under the most adverse environmental conditions. Full range of frequencies to 250kc. (Complete line of transistor drivers complements these magnetic circuits.)

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Variable word and message length. Read-Write cycle speeds to 100 kc., programming for sequential or random access, destructive or non-destructive read-out. Compatibility with TDCs permits direct communication between system's logic and memory areas. Built to your specifications from standard modules for prompt delivery.

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To help you learn about digital applications and system design with Epsco Components, we offer a seminar program with an operating demonstrator.

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Control ENGINEERING

AUGUST 1960
VOL. 7 NO. 8

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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Postmaster: Please send form 3579 to Control Engineering, 330 W. 42nd St., New York 36, N. Y.

a new look in counters

AND NEW RELIABILITY, TOO

CMC was first to introduce the all-transistor 10 megacycle counter. Now CMC scores another important first with its complete new line of vacuum tube counting, timing and frequency measuring equipment. Note the clean, functional lines of these tastefully styled instruments... user engineered to eliminate costly "cockpit trouble". These instruments are the most reliable vacuum tube counters ever built. In the counter-timer below, for example, nine tubes have been eliminated. New modular circuitry simplifies maintenance and reduces weight. Unitized construction is exceptionally rugged. And to further simplify matters, all models have three key components in common—input amplifiers, power supplies, and shaping circuits. In short, these instruments will give you long, trouble-free operation.

BUT SEEING IS BELIEVING—Your nearby CMC engineering representative will be happy to arrange a demonstration and provide complete technical data. Or you can write us direct.

CMC's Model 226B Universal Counter-Timer (1 mc) leads a complete new line which includes a 220 kc universal counter-timer, a time interval meter and a frequency-period meter.





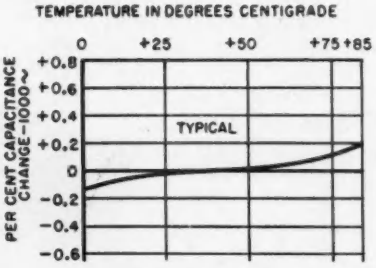
PRICES:
Model 226B, $1175; Model 226BN, illustrated, $1445 with Nixies; Model 225C, $900; Model 203B, $995; Model 251B, $915. Rack mount $10 extra. F.O.B. Sylmar, California.

Computer Measurements Co.
A Division of Pacific Industries
12970 Bradley Avenue, Sylmar, California
Phone: EMpire 7-2161

SEE US AT WESCON, BOOTH 633

CIRCLE 5 ON READER SERVICE CARD

New Film Dielectric Displays Unusual Stability





A new duplex plastic film dielectric developed and patented by the Sprague Electric Co. displays practically a zero temperature coefficient of capacitance over operating ranges up to +85 C. The retrace on return to room temperature is within ± 0.10%.

This new dielectric is currently being used in Sprague Electric's ISOFARAD Capacitors which are finding wide application in critical circuits of color TV receivers. The insulation resistance and dielectric absorption characteristics of these capacitors approach those of polystyrene film capacitors. ISOFARAD capacitors also are said to be superior to silvered mica capacitors in insulation resistance. Their tubular shape makes them more adaptable than silvered mica units for machine insertion on printed wiring boards. For practical purposes, their capacitance stability is equivalent to the more expensive silvered mica units.

Capacitor sections are of extended-foil design and are housed in pre-molded phenolic shells with plastic-resin end seals for protection against moisture and mechanical damage. Standard ISOFARAD Capacitors are rated at 500-volts d-c and are available with capacitance tolerances as close as ± 5%.

For complete technical data on ISOFARAD Capacitors (Type 145P), write for Engineering Bulletin 2073A to Technical Literature Section, Sprague Electric Company, 407 Marshall Street, North Adams, Massachusetts.

SHOPTALK

Red hot from Moscow

While the home office staff drooled jealously in New York, Derek Barlow, CtE's European editor, fired a cable or two a day from the first international congress of the International Federation of Automatic Control (IFAC) in Moscow. Besides making us feel as though we were there (or at least wishing we were), the cables form an extremely interesting diary of a delegate's day-to-day experiences at IFAC.

The IFAC meeting dates are such that while your Shoptalk editor writes this, we're still receiving cables and looking forward to getting Derek's roundup report when he returns to England immediately after the meeting. But fear not, part of this issue is being held up far past our regular closing date so that we can bring you all the news from this "summit" in control as soon as it arrives. Don't miss it.

Special report on guidance techniques

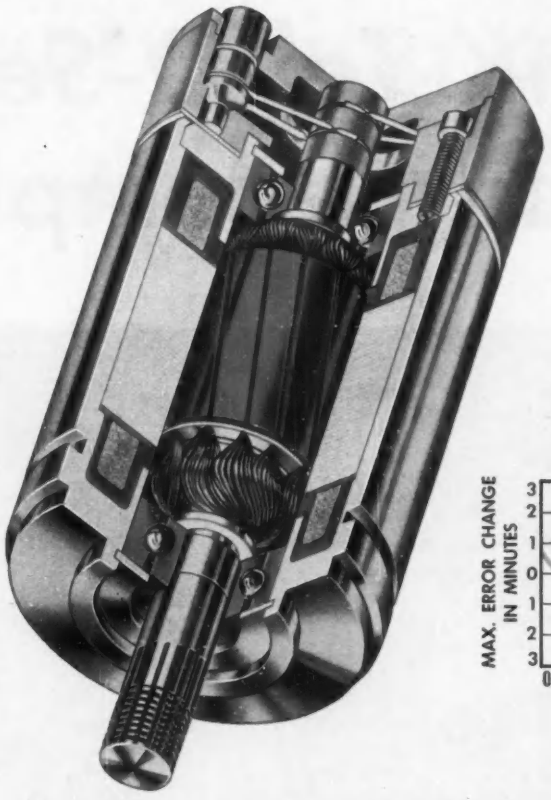
This is just a reminder so that you make sure to read the special report on "The System Characteristics of Modern Guidance Techniques" starting on page 85 of this issue. Coordinated by Dr. Charles J. Mundo of Raytheon and prepared by experts from three companies, this treatise covers inertial navigators, guidance radars, Doppler radar techniques, celestial navigators, and perceptive systems. Extra copies of this report can be obtained for 65 cents by circling number 504 on the Reader Service Card.

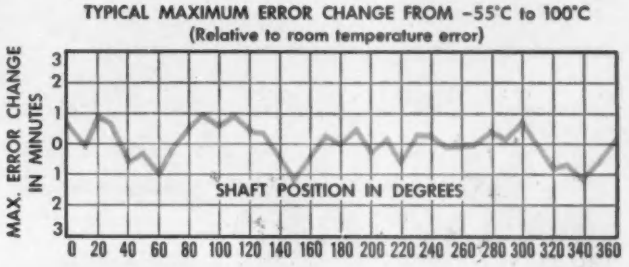
How far have automatic systems penetrated industry?

For the answer to this question save time to peruse the September issue of CONTROL ENGINEERING. Always a special integrated issue, this year the September theme is "Automatic Systems in the Plant", selected application studies of controls at work in everything from interplant business control to automatic materials handling. Emphasis is on the WHY of each application: Did it reduce reject rate? Increase throughput? Cut in-process inventory? More details on this issue are given on page 175 under "Coming Next Month".

Consulting editor goes up and over

Congratulations are in order for Dr. Eugene M. Grabbe, long standing CONTROL ENGINEERING consulting editor. Gene moves up to vice-president of the newly formed Compagnie Europeenne d'Automatisme Electronique and over to Paris, France. The new company is a joint-venture corporation of Thompson Ramo Wooldridge, Inc. with Compagnie Generale de Telegraphie sans Fil (CFS) and Intertechnique of France to manufacture and sell industrial control computers in the European Common Market.





Ketay size 11 synchros use MIL-S-20708 as the minimum standard

KETAY, a name synonymous with synchros, now offers immediate delivery on a complete line of size 11 synchros that meet or surpass MIL-S-20708.

Units are stable over the entire temperature range

Ketay has developed a special potting compound that now makes possible operating stability over the entire temperature range of minus 55° to plus 85°C. (see graph.) Higher temperature range units with these same characteristics, (−55°C to +200°C) are available on special request. In addition metallic parts have the same coefficient of expansion.

Synchro units feature thru-bore construction and precision design which assure higher accuracy and longer life.

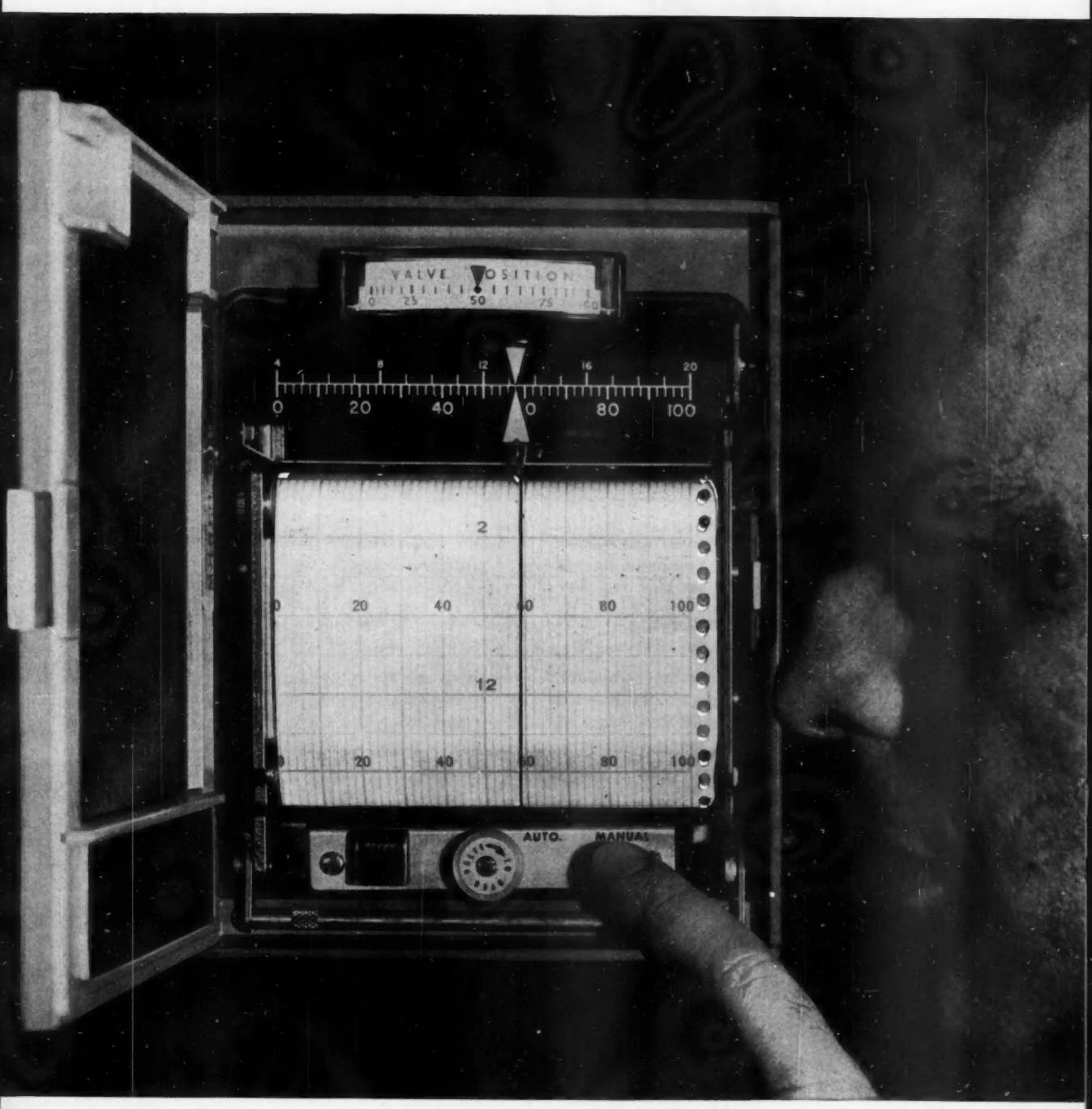
- Increased strength and resistance to shock, vibration and moisture is achieved because stator is potted in housing. Bearing bores and stator are machined simultaneously to accept rotor.
- High accuracy because of mechanical and electrical symmetry.
- Increased accuracy is achieved by the improved positioning of rotor and stator, with fully controlled rotor O. D. and air gap. Units available in accuracy of 3′ of arc.
- Ketay techniques of manufacturing, assembling and precise testing with highly accurate equipment assure product reliability of the highest quality available.

For more information about the size 11 line or other synchros from size 5 through size 31 please write to

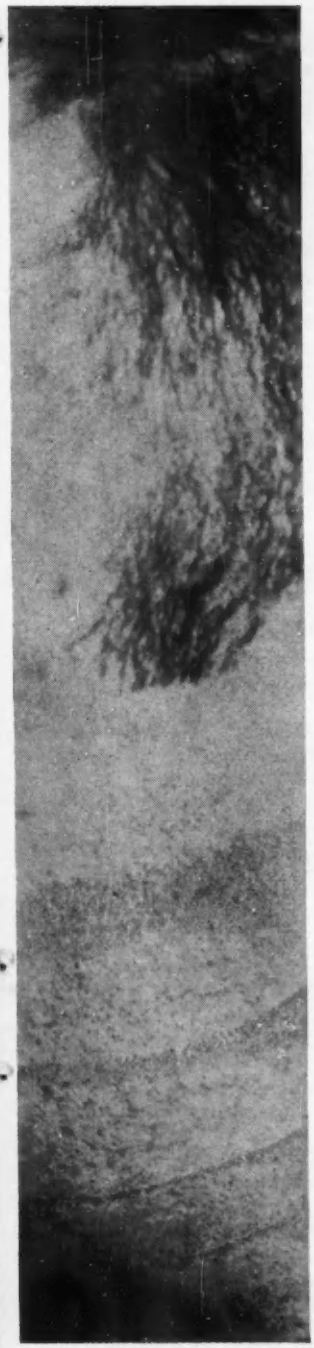
NORDEN

KETAY DEPARTMENT
NORDEN DIVISION
UNITED AIRCRAFT CORPORATION
COMMACK, LONG ISLAND, NEW YORK

New *ElectriK Tel-O-Set*... needs in a single compact



everything an operator control station



This Honeywell electric control station meets all of your requirements for operator convenience.

One compact case houses *every* function the operator needs to supervise a control loop: indication of process variable and set point on the same scale; the controls needed to switch from automatic to manual; controls for manual control; and indication of valve position.

The *ElectriK Tel-O-Set* control station assures easier bumpless transfer than ever before available because there's no need to "line up" or "match" pointers. A null balance indicator eliminates guesswork, and the transfer doesn't have to be hurried since the valve remains under control during the transfer.

You can also order the controller with the proportional band, rate, and reset adjustments on the front of the panel conveniently located below the control station, or at the rear of the panel.

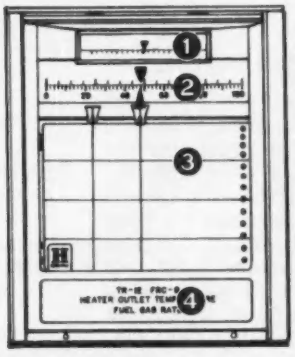
These are just a few of the features that make the new *ElectriK Tel-O-Set* control system an outstanding value. Your Honeywell engineer can give you complete details. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Fall River, Massachusetts.

75th YEAR — PIONEERING THE FUTURE

Honeywell

First in Control — SINCE 1885

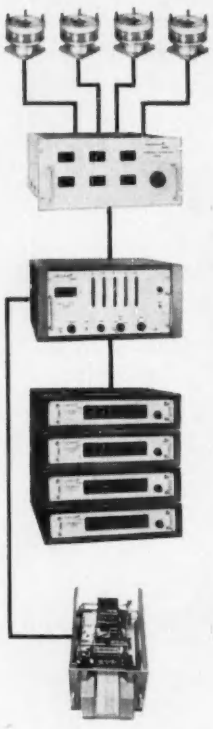


1. Valve position indicator continuously indicates controller output when on automatic control.
2. Set point index is conveniently located on same scale as process-variable pointer; you can see from a distance any deviation of variable from set point.
3. Rectilinear 4-inch calibrated chart is easy to read. At standard chart speed, four hours of recording is always visible. Unit has daily chart tear off or 30-day rewind. Both recorder and control station take the same 5½" x 6" panel cutout.
4. You get bumpless switching from automatic to manual control because you don't have to match pointers. In the balance position, the valve position indicator is part of a null circuit that compares controller output and manual output. When indicator reads 50%, both outputs are perfectly matched.

MEASURING ROTARY SPEED?

Now you can assemble complete digital systems using only standard components. All equipment is matched output-to-input to save engineering time and the cost of specially-tailored hardware. The simple system below may be expanded ten-fold in complexity.

ASSEMBLED BUILDING BLOCKS MAKE A DIGITAL SYSTEM...



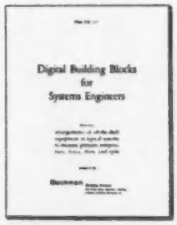
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Beckman printer records all speeds in rpm



Write for free 16-page survey of illustrative systems for measuring speed, pressure, temperature, force & flow.

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INSTRUMENTS IN YOUR FUTURE 25 YEARS 1935-1960

T33

FEEDBACK

Punch,

To the Editor—

I have for some time been a reader of Control Engineering and, as I am a busy person, I look to such publications as a means of keeping up-to-date in advances in technology, new products and new techniques.

I therefore resent magazines being padded by such articles as the one in your April issue entitled "Transistor-Relay Hybrids". This unit "Transistorized Trigger Circuit" provides neither "breakthrough", nor can it claim to be unique; it is merely common or garden standard practice which has been used for many years.

C. Day
Jarry Hydraulics Ltd.
Montreal, Canada

counterpunch and right cross.

To the Editor—

First, Mr. Day, in his anxiety to criticize, has jumped to a conclusion before fully understanding what is being said. The breakthrough is not in the transistorized trigger circuit but in the provision of a close differential relay characteristic.

Second, experiment will demonstrate to Mr. Day that the establishment of a transistor-relay hybrid with less than 1% differential is not a "garden standard" design.

Third, though the described hybrid was developed by the author some time ago, if Mr. Day is keeping up-to-date with technological advances, he will find that a close differential transistor relay hybrid, as described, capable of operating to the tolerances specified over a temperature range of −55°C to +100°C, is neither common practice nor regarded as a standard achievement of years standing.

A. N. DeSautels
Maico Electronics
Minneapolis, Minn.

Where can I buy 'em?

To the Editor—

We read in the January issue of Control Engineering your report on "Control Enters a New Decade." We find it very interesting and should like very much to get from you some supplemental indication of the firms that will provide in the U.S.A. the following automatic control elements:

1) single modules for all logical connective operations: AND, OR, NOT, NOR, delay, conversion, and memory;
2) packages containing functional combinations of logical operations;
3) matchbox-size epoxy potted cans for the following functions:
   a—counting
   b—entire shift register
   c—code conversion
   d—microminiaturized magnetic digital-to-analog conversion
   e—comparison for direct control action

Prof. Antonio Scortecci
Director, Istituto Siderurgico
Genoa, Italy

Among manufacturers of single logic elements (available from stock) are:

Engineered Electronics Company
506 East First Street
Santa Ana, California

Harvey Wells Electronics
14 Huron Drive
East Natick, Massachusetts

Digital Equipment Corporation
Maynard, Massachusetts

Computer Control Corporation
Wellesley, Massachusetts

Wang Laboratories
12 Huron Drive
Natick, Massachusetts

Walkirt Company
14 West Hazel Street
Inglewood 3, California

Many instrument manufacturers produce functional combinations of logical elements. In addition to the manufacturers listed, you might try contacting:

Dymec Division
Hewlett-Packard Corporation
395 Page Mill Road
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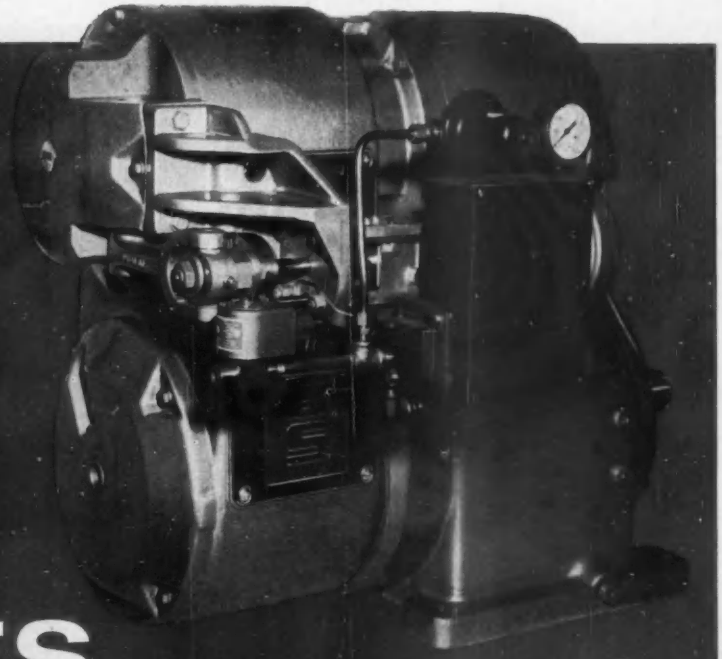
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AIRtrol: automatic process control with REEVES VARI-SPEED MOTODRIVES



REEVES AIRtrol, in an open or closed loop system, automatically and continuously corrects operating speeds to compensate for variations in materials or processes. AIRtrol controls variable output speeds from temperature, liquid level, pressure, weight, peripheral speed and proportional flow signals. Here are important reasons why REEVES AIRtrol on REEVES Vari-Speed Motodrives, are performing efficiently on conveyors, pumps and machine tools . . . and in process industries handling solids and liquids.

- Exclusive contoured cam design results in output speed in direct proportion to instrument air signal. This permits linear (straight line) output speed over the entire output speed range of the drive.
- Cam also provides a sensitive and stable control throughout the speed range . . . automatically.
- AIRtrol operates on a 3—15 psi. air signal from any standard process-instrument. Exclusive "Span Adjustment" feature makes it possible to use the full signal . . . locking the 3 psi. signal to minimum speed and 15 psi. to maximum speed of the motodrive. This applies to units of 2:1 speed range, as well as 10:1.
- REEVES AIRtrol is available on all REEVES Vari-Speed Motodrives—¼ hp. through 40 hp., 2:1 through 10:1 speed range, with variable output speeds as high as 4660 to as low as 1.71 rpm.

For complete information on REEVES AIRtrol, call your nearest Reliance Sales Engineer.

G-1654

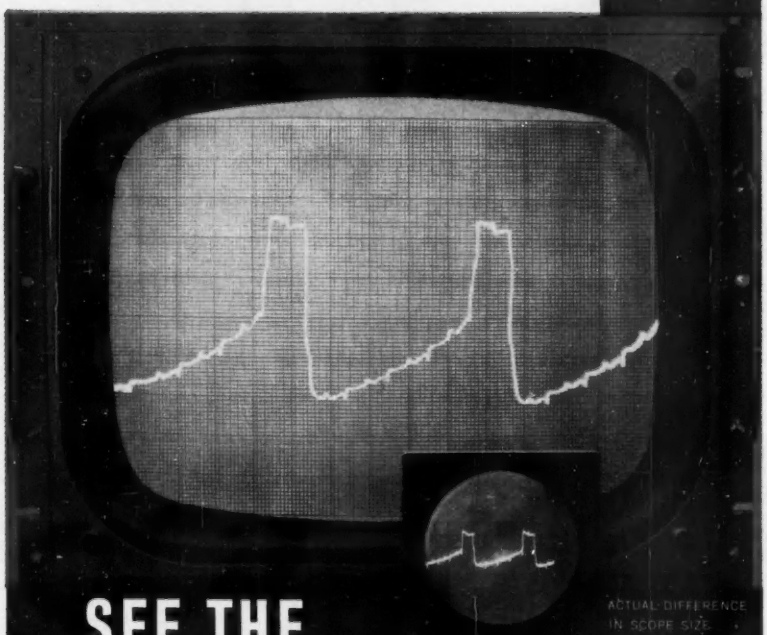
Product of the combined resources of Reliance Electric and Engineering Company and its Master and Reeves Divisions

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Duty Master A-c. Motors, Master Gearmotors, Reeves Drives, V★S Drives, Super 'T' D-c. Motors, Generators, Controls and Engineered Drive Systems.

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• in *picture size* that presents so much more information • in *accuracy* that allows you to observe even minute details • in *reading ease* that eliminates operator errors and fatigue.

These are some of the differences you see with ITT large scope viewing—advantages you don't get with conventional scopes.

In both 17" rack-mounted and 21" cabinet-mounted units, ITT's precise magnetic deflection system provides excellent resolution and linearity for a wide variety of applications...for teaching, demonstration or exhibition...for telemetering, production testing, waveform analysis, computer readout, X-Y plotting, data plotting and medical observation...easily adapted for bar graph presentation and monitoring.

Complete application and specification data is available at your ITT Instruments representative or by writing us direct for Data File CE-1045-1.

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Ed.

Ethical experiment succeeds.

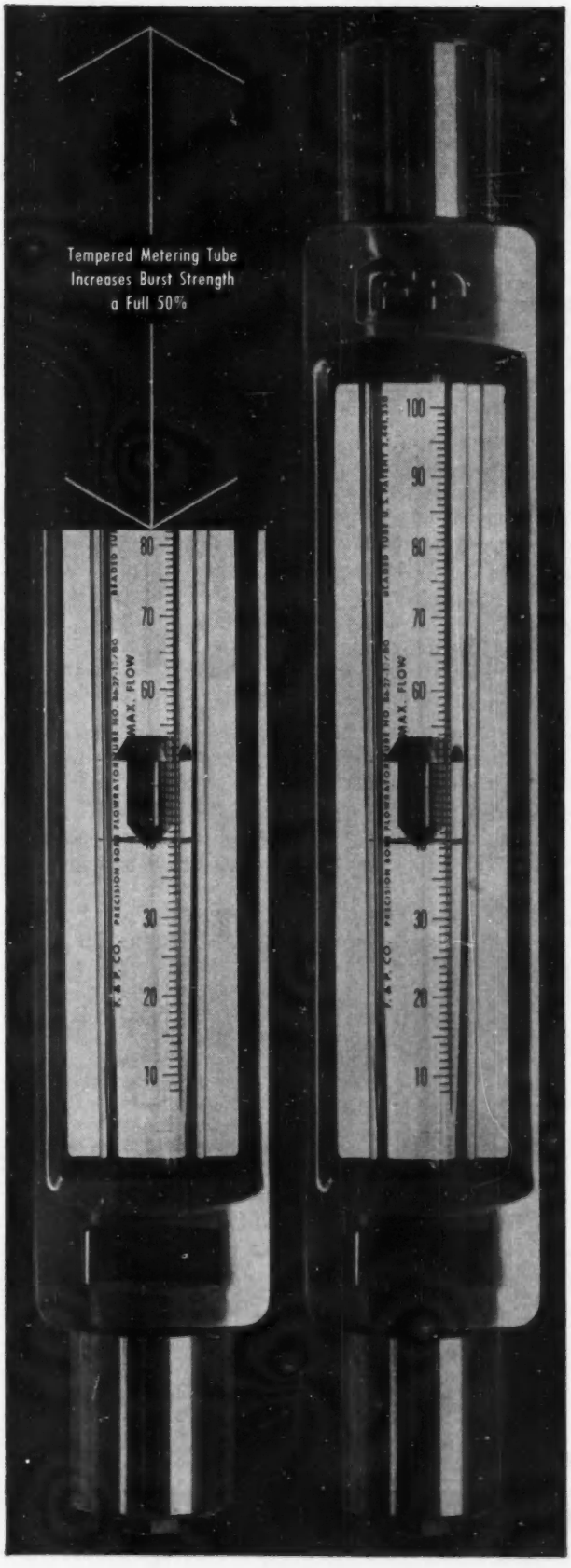
To the Editor—

Thank you for bringing to your readers' attention the "Code of Conduct" used by the Sixth National Flight Test Instrumentation Symposium, through your May 1960 editorial, "An Experiment in Ethics". The Steering Committee of the Aero-Space Div. of the Industries Dept. of ISA established a code of ethics in order to continue a policy that vendors providing hospitality suites had voluntarily used for several years. The atmosphere these vendors created helped the Symposium establish a reputation of a meeting at which valuable informal technical discussion easily occurred. This reputation attracted vendors as a place to make valuable contacts. Competition between vendors inevitably arose. The "Code" was established in an attempt to prevent "free-for-all conduct of business" from getting out of reasonable bounds.

The reaction of all vendors providing hospitality suites at the Sixth Symposium was gratifying. In general they appreciated having a code established. They supported the idea. To the best of my knowledge, they voluntarily maintained the ethics outlined. It is planned to continue the use of this principle for our future meetings. Adherence is voluntary by symposium participants. The primary "policing action" by the Symposium Committee was accomplished by the publishing of the code.

From the experience of the Symposium Committee, we believe the "Experiment" was successful. Thank you again for your recognition of our efforts towards improving "value received" for those attending symposia.

Harold K. Cheney,
General Chairman
Sixth National Flight Test
Instrumentation Symposium
San Diego Calif.



New Rotameters Take 50% Higher Operating Pressures

Now, you can use glass tube rotameters where you've never dared use them before. New tempered glass metering tubes take up to 50% higher operating pressures. Install them with complete assurance on process lines that formerly required metal tube meters. And gain a desirable extra margin of safety *wherever* rotameters are used.

How F&P did it

This major advance in flowmetering art developed from two well known facts:

1. Glass has ten to twenty times more compressive strength than tensile strength.
2. Endwise pressure and uneven peripheral compression (as from a stuffing box) impart a substantial tensile component.

First F&P eliminated that tensile component by developing the unique O-ring "floating tube" seal introduced in the 2700 Series flowmeter.

Now, F&P has developed a special method of tempering the precision borosilicate metering tube that boosts compressive strength *without causing distortion!*

Be sure you get a tempered metering tube

Tempered borosilicate metering tubes are now being supplied as standard equipment with all Series 2700 flowmeters at no additional cost. But you *must* specify this make and series to enjoy the increased pressure rating.

Get complete information...Now

Write for your copy of Bulletin 91-123, "The Rotameter Sheds Its Limitations".

Fischer & Porter Company, 780 County Line Road, Warminster, Pennsylvania.

FP FISCHER & PORTER COMPANY

Complete Process Instrumentation

These MANUFACTURING AFFILIATES carry Fischer & Porter engineering designs to the far corners of the earth: FISCHER & PORTER (CANADA) LTD., DOWNSVIEW, ONTARIO • FISCHER & PORTER LTD., WORKINGTON, CUMBERLAND, ENGLAND • FISCHER & PORTER G.m.b.H., GROSSELLERSHAUSEN, BEI GOTTINGEN, GERMANY • FISCHER & PORTER N.V., KOMEETWEG 11, THE HAGUE, NETHERLANDS • FISCHER & PORTER Pty. LTD., 184 HANNA ST., SOUTH MELBOURNE, VICTORIA, AUSTRALIA.

Recorders of the future will have

Powerful Servomatic Motors in both TRANSCOPE® Pneumatic and Electronic Recorders give unprecedented accuracy of records . . .

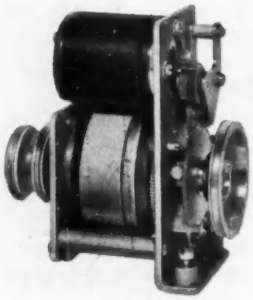
One of the reasons why the 90J (pneumatic) and 700J (electronic) recorders have become the most wanted miniature instruments is this exclusive Taylor feature . . . powerful Servomatic motors that give more precise pen positioning than ever before. Check these benefits:

- Threshold sensitivity of 0.1% to input signal.
- 150 times more power than bellows type used in conventional pneumatic recorders. Over 1,000 times the output power of galvanometer systems in electronic instruments.
- Unprecedented standards of accuracy—½ of 1% in standard instruments—¼ of 1% optional.
- 3 months' ink supply *mounted on the pen*—no capillary.
- Integral heavy duty process alarms in recorder cases . . . 2 per servo . . . up to 6 per recorder.
- No flimsy linkages and levers.
- Truly rectilinear chart—no curved time lines.

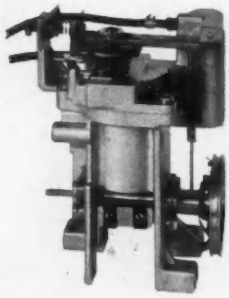
Servomatic motors also allow these optional features: alarm contacts; retransmitting potentiometer; function generation; digital output with encoder discs.

"Hunk of Brass" Test. Ask your Taylor Field Engineer to show you the 'Hunk of Brass' test — conclusive proof of the power of Servomatic motors to assure positive, precise positioning of the pen.

For full details of TRANSCOPE servo operated recorders and their many superior features, write for **Bulletin 98335** (electronic) or **Bulletin 98286** (pneumatic). Taylor Instrument Companies, Rochester, New York, and Toronto, Ontario.



700J (electronic) servo motor is 2 phase, size 15, 60 cycle, 117 volt—built to military specifications. Precision gearing couples the servo to a precise feed-back device with high torque.



90J (pneumatic) servo motor is essentially a power piston with a built-in positioner. Solid construction assures long, trouble-free life.

Taylor Instruments

Servo Power



TRANSCOPE 700J
ELECTRONIC
RECORDER

...Taylor has it NOW!

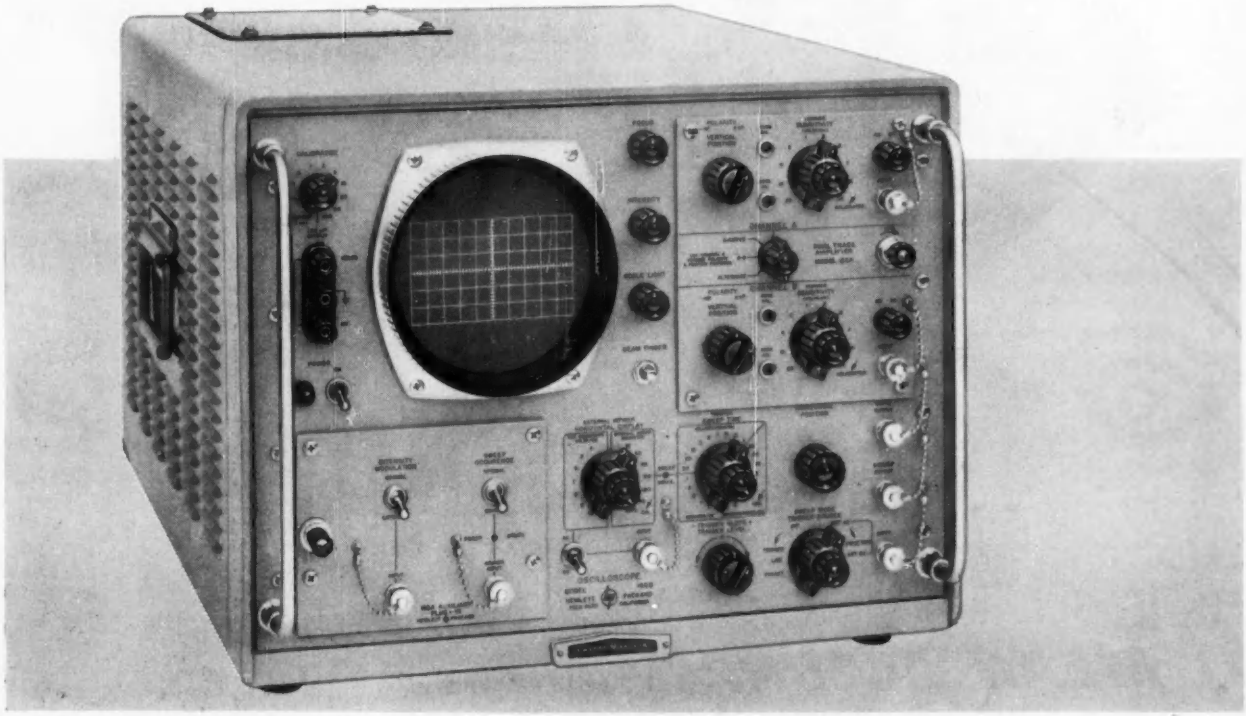
MEAN ACCURACY FIRST

CIRCLE 15 ON READER SERVICE CARD

hp 160B

Presented proudly

The hp 160B—a new 15 MC oscilloscope built to exacting MIL specifications; most versatile oscilloscope ever offered.



Here are some of the outstanding features:

New plug-in versatility **Horizontal plug-ins.** New 166 series horizontal (time axis) plug-ins add a whole new dimension of flexibility to the basic oscilloscope. First two of the series are: **166C Display Scanner** making the 160B the world's first major scope with an *X-Y recorder output. This output covers the full scope bandwidth and makes possible large, high resolution, permanent X-Y records of repetitive waveforms.* **166D Sweep Delay Generator** establishing new convenience for conventional sweep delay measurements. A unique mixed sweep feature permits detailed analysis of one pulse in a wavetrain while retaining a display (on a slower time scale) of the entire wave preceding the pulse of interest. Thus, you view the exact pulse or segment desired while still retaining presentation of the earlier display. Extremely high magnifications are possible with appropriate settings of sweep controls.

Vertical amplifier plug-ins. New 162 series plug-ins will include new amplifiers permitting scope operation under many different input conditions. Typical plug-in is 162A Dual Trace Amplifier, 20 mv/cm unit permitting simultaneous viewing of two phenomena or differential amplification of signals dc to 14 MC.

Military quality — Using premium components throughout, the 160B is designed to meet the highest standards of ruggedness, accuracy and dependability. It follows MIL-E-16400B for shock, vibration, humidity and temperature. Premium features include high stability tube-transistor circuits, regulated dc filament voltages, power transistors in efficient heat sinks, circuits on translucent epoxy-glass, simplified layout.

Easy to operate — Model 160B control array is traditional and logical. No special training is required to operate the 160B. Your set-up time and measurements are simplified with improved *preset triggering* and an *automatic beam-finder*. The first means that one preset adjustment insures optimum triggering for almost all conditions (even signals down to 2 mm deflection). The second means that with the press of one button the beam is instantly located and "held" until you center your trace.

SPECIFICATIONS

SWEEP GENERATOR:
Internal Sweep: 24 ranges, 0.1 μsec/cm to 5 sec/cm; vernier to 15 sec/cm
Magnification: 7 ranges, to 0.02 μsec/cm
Triggering: 2 mm minimum, internal, power line or vertical input signal. External 0.5 v peak to peak
Trigger Point: Pos. and neg. −30 to +30 v
Sawtooth Output: −50 to +50 v
Gate Output: 50 v pulse

HORIZONTAL AMPLIFIER:
Bandwidth: dc to 1 MC
Sensitivity: 7 ranges, 0.1 v/cm to 10 v/cm; vernier to 25 v/cm
Input Impedance: 1 megohm, 30 pf shunt

CALIBRATOR:
Type: 1,000 cycle square wave, 1 μsec rise, decay time
Voltage: 9 ranges ± 3%, 0.2 mv to 100 v peak to peak
Current: 5 ma peak to peak, ± 3%

CATHODE RAY TUBE:
Type: 5AMP mono-accelerator, flat face, P1, P2, P7, P11 screen; 5,000 v accelerating potential
Deflection Sensitivity: 20 v approx.; intensity modulation 20 v pulse to blank

PRICE: 160B Oscilloscope, $1,850.00

162A PLUG-IN AMPLIFIER

Sensitivity Range: (Each channel) 0.02 v/cm to 50 v/cm, 10 ranges; 0.02 v/cm to 20 v/cm. Accuracy ± 5%
Pass Band: Dc coupled, dc to 14 MC, 0.025 μsec rise time
Ac coupled, 2 cps to 14 MC
Differential Input: Both attenuators may be switched to one channel and adjusted separately. Common Mode Rejection at least 40 db at max sens.; at least 30 db with attenuators
PRICE: 162A Plug-In Amplifier, $350.00

Data subject to change without notice. Prices f.o.b. factory.

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6038

For fast, high-resolution servo positioning

Inland d-c torque motors

From 0.1 to 3000 pound-feet

High torque-to-inertia *at the output shaft*

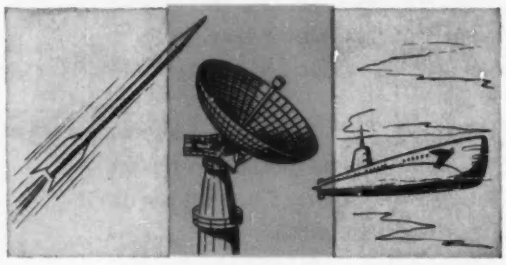
A typical stabilization application requiring a peak torque of 60 ounce-inches now uses an Inland torquer with a torque-to-inertia ratio of 5350 radians/sec.^{2}. This torquer replaces a gear train servo motor that had a ratio at the output shaft less than *one-tenth* that of the Inland torquer.

Direct drive promotes system accuracy

Direct drive without servo motor gear trains reduces friction and eliminates backlash and elasticity, leading to better over-all system accuracy.



COMPACT PANCAKE SHAPE now available in d-c torquers through exclusive Inland design



Exclusive commutator and brush rigging design

Patented features enable Inland to combine the compact pancake configuration with low-power input —high-torque output characteristics of a d-c torquer.

TYPICAL RATINGS FOR 20 OZ.-IN. TORQUERS

	T-1321-D	T-1321-B	T-1321-C
PEAK TORQUE, OZ.-IN.	20	20	20
VOLTS AT PEAK TORQUE, STALLED AT 25°C	31.4	24.8	39.6
AMPS AT PEAK TORQUE	1.82	2.25	1.46
TOTAL FRICTION, OZ.-IN.	0.5	0.5	0.5
ROTOR INERTIA, OZ.-IN. SEC.^{2}	.001	.001	.001
WEIGHT, OUNCES	5	5	5

Inland Power Amplifiers

Inland makes a complete line of power amplifiers for systems duty with Inland torquers whether in airborne, shipboard, or ground service. Specification sheets available on request.

For complete data on these or other d-c pancake torquers up to 3000 pound-foot output, address Dept. WE, Inland Motor Corporation of Virginia, Northampton, Massachusetts.

Factory: Radford, Virginia

INLAND MOTOR CORPORATION OF VIRGINIA

A SUBSIDIARY OF KOLLMORGEN CORPORATION

NORTHAMPTON, MASS.

D. J. Pompeo
solved the tough ones

Instilled with a great drive for getting things done, Dominic J. Pompeo has set a breakneck innovating pace as founder and head of the Instrumentation Dept. of Shell Development Co. He is responsible directly or indirectly for the development of 90 devices, many of which are now being licensed to instrument manufacturers serving the process industry—instruments that range from a recording retractometer to a reflux ratio controller. His unexpected retirement in June because of a serious illness left a void at Shell Development, and the petroleum industry lost one of its most perceptive control men.

Almost since the day he joined the original staff at Shell Development, "Pomp" has been a thinker and a doer in measurement and process control. Just this spring, ISA recognized his long string of accomplishments by electing him a fellow of the society; he was only the third person to be so honored. His award was made "in recognition of his attainments in advancing the science and technology of instrumentation and particularly for his distinguished contribution in the field of analytical instrumentation for the petroleum industry".

Instrumentation was not the sophisticated area of study it is today when Pompeo first arrived at Shell Development. He had been hired to join the Dept. of Glass Blowing and Instrumentation (with emphasis on the former) because of his proficiency as a glass blower, demonstrated at a part-time job at California Institute of Technology. Born in New Jersey, Pompeo learned the art before he moved to the West Coast. When he matriculated at Cal Tech to study physics, his glass blowing skill helped pay his way. After graduation in 1926, Pompeo stayed on at the institute as an instrument and glass blowing specialist, working with the well known physicist Dr. Robert Millikan. Typical of the kind of device he had to build: a light indicator fashioned from the wing of a fly, delicately attached to a superthin, hand-drawn sliver of glass.

Despite his almost two years of instrumentation experience when he joined Shell in 1928, Pompeo's first few months were spent at glass blowing. But he was quick to sense that a revolution was about to start in process measurement. The instrument man was then concerned with only four measurements of environment: temperature, pressure, level, and flow, while analytical measurements were relegated to the laboratory and the "wet chemist". Pompeo was the first at Shell Development to recognize that this situation in measurement was about to change.

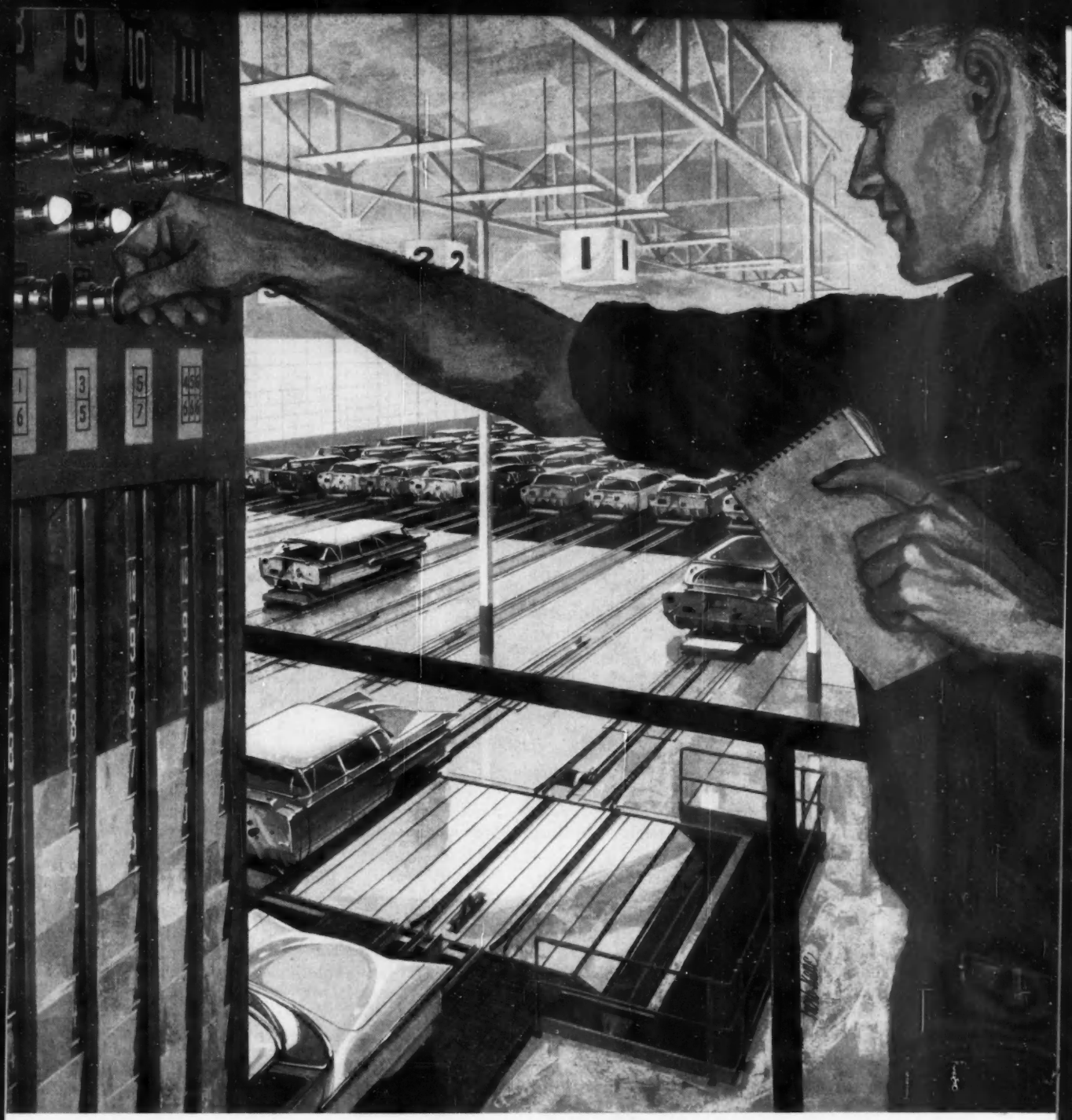


"Pomp's greatest contribution to the field", says another close Shell Development associate, "has been a crusade to put analytical instruments in process control. He was advocating it years before anyone was doing it. And today, we are doing it largely because of Pomp." The emphasis on which Pompeo insisted was for continuous instrumentation.

Under Pompeo's watchful eye, instrumentation at Shell Development gained stature, and four separate sections were formed, devoted solely to measurement and control: Laboratory Instrument Development, Plant-type Analyzers, Quality Control Instruments, and Process Instruments and Control Systems Analysis. Despite the categorization, Pompeo never let the name of a section prevent a man from pursuing an idea into a different area.

As he watched his analytical instrumentation crusade bear fruit, Pompeo turned to other problems in process control. The one that caught most of his attention in recent years: the fully automatic plant, made possible by an amalgamation of instrumentation and control.

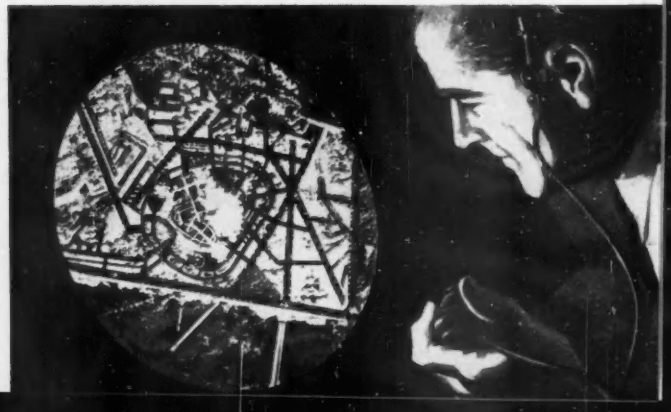
When requests for instrument development funnel into the Instrumentation Dept. from other Shell divisions, Pompeo liked to remark: "These are the real tough problems, because the chemists in the laboratory solve all the easy ones themselves." Solving the tough problems was the hallmark of Dominic Pompeo's career in measurement and control.



What a memory! How do you check quality and record it on coils of tinplate up to three miles long? New Cutler-Hammer sensing, memory device does it. It's the first of its kind anywhere.



What a view! Here's a radar picture of all runways at Idlewild Airport. It's so clear you could identify a horse two miles away! Another Cutler-Hammer development.



CONTROL

What's new in control for automation?

An automatic warehouse that tells car bodies when to stop and go

Cutler-Hammer system directs car bodies to and from storage area for a major automobile manufacturer. The need was for a buffer storage area for car bodies between the assembly plant and the body building plant.

Before this storage area idea was conceived, car bodies went from the line of the body plant right to the line of the assembly plant. If one line had to shut down, the other did, too.

Cutler-Hammer systems control men developed the electrical control that sorts the car bodies coming from the body plant to one of eleven storage conveyors. Also, any body style can be taken off the conveyor and sent to the assembly line.

And, now? No shutdowns in one plant if the other is shut down temporarily. Any body style needed can be put on the assembly line. Couldn't be done before. So now, parts shortages affecting one body style don't affect production.

The conveyor system installed only last year is paying big dividends in reduced assembly line costs. As a result, several similar installations have been ordered.

The importance of an electrical control man. A Cutler-Hammer control man can bring wide experience to your automation planning table. He's handled many different products. He's worked with many different systems. With the proper control recommendations, many thousands of dollars can be saved.

The big change at Cutler-Hammer. You can see a change at Cutler-Hammer. We've prepared for the expected growth in the sixties with new, better products, new plant capacities, new engineering talent. If you're planning ahead, we'd like to talk to you. We could save you time and money in your automation planning. Contact the Cutler-Hammer sales office nearest you to see how.

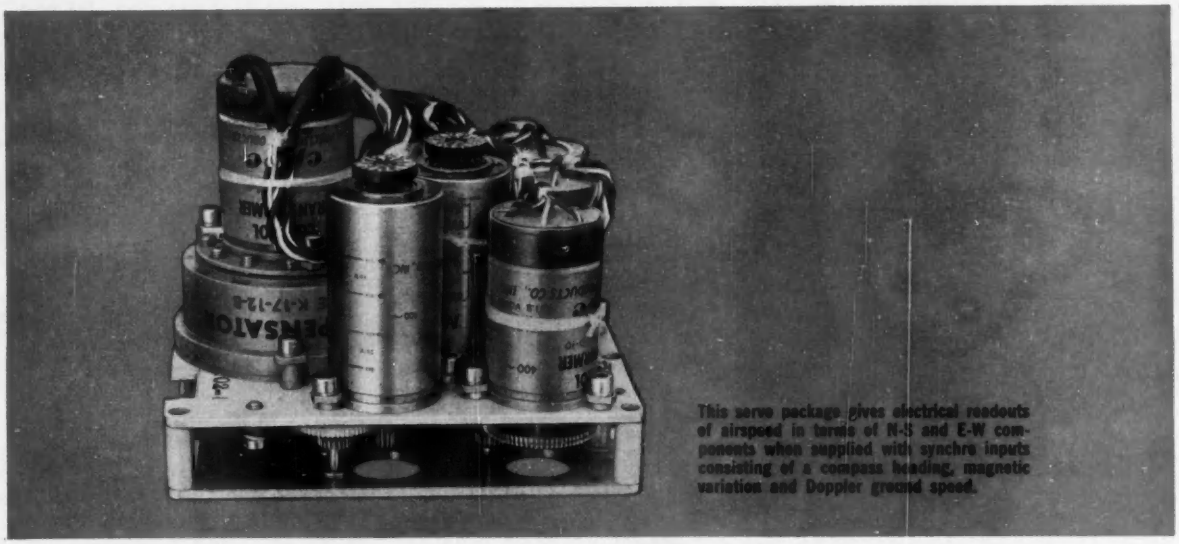
Automation is more efficient when the control expert is called in early.

WHAT'S NEW? ASK...

CUTLER-HAMMER

CONTROL

Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.



This servo package gives electrical readouts of airspeed in terms of N-S and E-W components when supplied with synchro inputs consisting of a compass heading, magnetic variation and Doppler ground speed.

NOW BUY cppc QUALITY ACCURACY RELIABILITY

IN cppc SERVO MODULES

In designing and producing servo modules to *your* specifications, Clifton Precision Products Co. manufactures 95% of the parts used. What does this mean to you? It means that the same high accuracy, reliability, and quality which go into the manufacture of CPPC synchros are maintained in CPPC Systems. This one source responsibility gives you the added advantage of a continuous Quality Control activity which guarantees a high quality product.

CPPC has had years of broad experience in researching, designing, developing, and manufacturing a wide variety of servo packages. A few examples of our products are shown on this page. Here at your service is a first class engineering design and manufacturing team from research through production.

Write for a more detailed facilities brochure or telephone Ken McGrath, Sales Department, HIlltop 9-1200 or our Representatives.

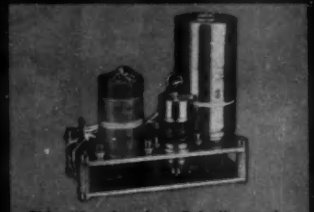
cppc SYSTEMS DIVISION

CLIFTON PRECISION PRODUCTS CO., INC.

Clifton Heights Pennsylvania



This "Synchronizer Drive" servo package is used to null out gyro signals before an aircraft's autopilot is engaged.



This "Synchronizer Drive" can be used to null out transmitter signals. A wide variety of gear ratios is available as well as the option of two speed operation.



This transducer servo package converts a mechanical shaft input into a linear precise electrical output when a 28v dc signal is applied. It is particularly useful in aircraft for position information transmission of air surface controls.

Newsbreaks In Control

● In Steel, New Power Means New Controls

Chicago—For the first time in the United States, a gas turbine is driving the blowers of a steel mill's blast furnaces. To control this unique power supply at the U. S. Steel's South Works, GPE Controls has developed a multivariable control system that regulates speed, acceleration, exhaust temperature, surge and flow configuration through startup, on-line, and shutdown operations. An interesting sidelight on the control system: it is based on wind tunnel control designs.

● New, Less Expensive, Continuous Contouring Control

Waynesboro, Va.—General Electtric Co. has developed a punched tape numerical control system which will bring the cost of automatic contouring control to levels comparable to point-to-point control systems. The new system, designated Mark Century, can program machining jobs that involve only straight cuts, slopes, and arcs of circles directly from engineering drawings without a computer. Input information required: length and direction of slope or radius and length of arc.

● Low Cost Approach to Computing-Control

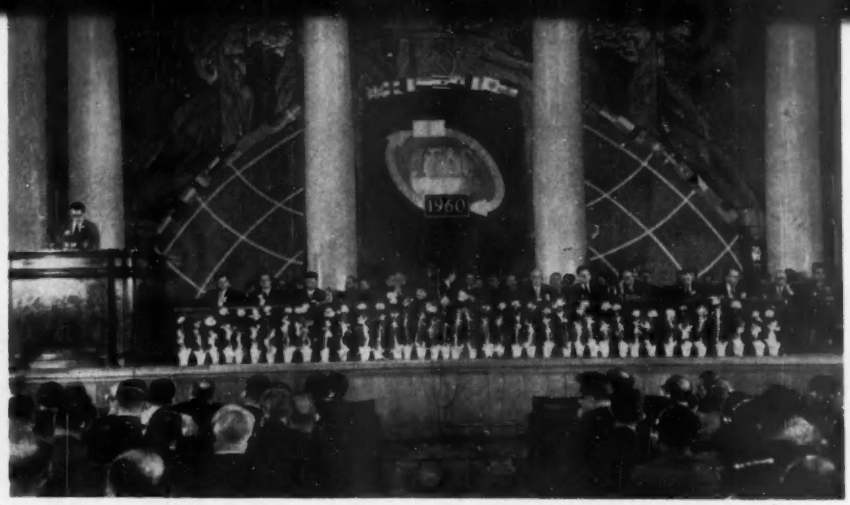
Chicago—A new low cost approach to computing-control will soon be announced by Universal Oil Products and Daystrom. The duo will offer availability of a computer-controlled refinery process that will use a Daystrom solid state special purpose digital computer called Flowcon to control UOP's Molex process for separating normal paraffins from isoparaffins with molecular sieves. Usable only in this one process, the control system is said to handle 24 variables. Reported price: $30,000.

● NMBTA Show to be a Control Show

Chicago—Exhibitors have started setting up the more than 1,000 machine tools that will be displayed at the September Machine Tool Exposition, sponsored once every five years by the National Machine Tool Builders' Association. Word leaking out of the International Amphitheatre is that the 1960 exposition will be a "control show". Says one expert, "This year's big innovations are all in control. There will be over 100 numerical control systems alone displayed. In addition, there will be a big play for programmed control and other electronic control systems."

● Japan to Build Giant Computer

Tokyo—Japan's Electrotechnical Laboratory has started construction of a giant computer, comparable to the IBM STRETCH and Remington Rand LARC machines, incorporating an experimental supplementary tunnel diode memory. Under development by Dr. Shigeru Takahashi, the memory will have a cycle time of 0.2 microsec, a capacity of 128 words. Addition times of the new machine will be about twice those of the IBM STRETCH: 0.5 microsec fixed decimal point and 1.5 microsec floating decimal point; multiplication time will be 5 microsec.



U. S.'s Harold Chestnut addresses the opening session of the IFAC meeting from a flower-decked stage in the auditorium of the huge Moscow University.

Russia Not So Shocking in 1960 Visit

When a 13-man delegation of the American Automatic Control Council visited Russia in the summer of 1958, members of the delegation were awed by the broad Soviet activity in control technology which they saw (a team report appeared in CtE, November '58, pp. 65-80). One reason the Soviets were able to make such an impression was that this visit had been Western control engineers' first comprehensive look at what was going on behind the Iron Curtain. Almost everything the visitors saw was somewhat unexpected. At last month's International Federation of Automatic Control Congress, however, western delegates who took advantage of the Moscow meeting to tour Russian industrial plants and institutes knew pretty much what to expect and were not so deeply impressed as the AACC delegation had been.

For one thing the Soviet hosts were still showing off the same exhibits that had impressed the AACC delegation two years ago. But what passed as impressive then was old hat in July 1960. For example, on the industrial tour were such sights as the first state ball bearing plant and the Smallpower car factory through which the Soviets steer all foreign visitors. There has been little new equipment added to either plant since they were opened almost five years ago.

Still the fountainhead of control theory for the entire Soviet Union is the Institute of Automatic and Remote Control in Moscow, its staff of 1,600 headed by Soviet academician V. A. Trapeznikov. Many of the Institute's top priority projects are the same ones that were getting top attention two years ago: for example, optimizing control and pneumatic computing components.

CtE's European editor cabled these impressions after a visit to the Institute during the IFAC Conference:

"Established three years ago to develop control systems for industry, the Institute of Automatic and Remote Control is proud of the hardware it has developed. Although Institute members were willing to show off their prototype models, they were not so willing to discuss how many actual installations had been made if any.

"One recent development the Russians are proud of is a reversible magnetic amplifier for dc machine tool control. An unusual high power transistor with large top-mounted cooling fins has been incorporated to transistorize the device's rectifiers and preamplifiers (which, the Russians say, are capable of both ac or dc operation). Other solid state devices under development are 2-Mc ferrite core magnetic amplifiers, nonlinear systems, and operational amplifiers for analog computers and magnetic modulators. The latter are replacing vibrator modulators in self-balancing potentiometers; they operate on inputs as low as 100 microwatts.

"Another pet project of the institute is the development of machines that automatically design circuits and other machines. So far one has been developed: a machine for designing relay circuits [Editor's note: this machine was displayed at the Russian Exposition held in New York last summer]. *The first model is a mechanical machine; a larger electronic device is under construction.*

"Automatic control of gas, oil, and utility distribution lines is a major problem in the Soviet Union, so it was no surprise to find the Institute had developed a long line telemetry system for such applications. Unconventional in design, the frequency modulated system crams 50 channels into a frequency range between 100 and 500 cps by combining two or three basic frequencies to extend channel capacity.

"Researchers have applied optimizing theory to improve information transmission efficiency of the system. To save bandwidth, the Soviets vary measurement accuracy as input signal conditions change. Here is how it works. When measuring a steady variable, accuracy is high; but the system is insensitive to fast rate changes. As the measured variable changes, system characteristics change to supply faster response but lower accuracy. Both pulse width and pulse rate vary in this operation. A constant variable is transmitted as a wide slow pulse; the signal of a dynamic variable would have a reduced pulse width and an increased pulse rate. [Editor's note: This system was described at the ISA Conference, September 1958.]

"Optimization is also the object of Dr. A. Feldbaum. He has built four different types of industrial optimizers and equipment for synthesizing self-adaptive systems—a device composed of multichannel optimizers controlling linear filters and nonlinear transform-

ers. The latter can accept up to 12 input variables. He has also built two single variable industrial optimizers with relays for possible application to optimizing oxygen-air ratios in open hearth furnaces.

"Dr. M. A. Aizerman is still at work on pneumatic computing elements, having expanded the scope of his work. [Editor's note: these units operate on a jet principle quite similar to those developed at the U. S. Army's Diamond Ordnance Fuze Laboratory and reported in CtE, May '60, p 26.] *He is now converting his laboratory prototypes into production designs."*

Visiting industrial plants, many delegates were shocked at what they saw. Conditions were often incredible: parts and materials were stacked apparently indiscriminately all over the working areas. Despite the Russians' heated discussions about automatic control, not too much has yet materialized in production plants as hardware. A typical example is the Sverdlov Machine Tool Plant where western delegates were told they would see production of programmed control machine tools. Although the plant was turning out milling machines, jig borers, and hydraulic copying lathes, none had programmed control.

Cabled CtE's European editor about this visit:

"I asked the plant director where was the programmed control or numerical control we had expected. He replied that 'continuous contouring controls are planned for next year's production, and point-to-point position controls will be fitted on the tenth jig borer to be built on a production line which the plant is just starting up.'

"This 1,500-employee plant is typical of many in Russia. It is working two shifts a day with 65 percent of the staff on the first shift. Three hundred designers back up the production staff. Although there is no reason to doubt the intentions of the plant director, it appeared that the control system development section has done little on program control. Their main efforts seemed directed at producing a wide range (2,000 to 1) continuously variable motor drive.

"The plant has standardized on a cross field amplidyne drive first introduced in 1952, one drive for each axis. The control has, in addition to over-all velocity feedback, both acceleration and rate of acceleration feedback to help stiffen the system.

"A programming control is available for heavy jig borers. The system is the one exhibited at the Belgium World's Fair last year.

"One interesting bit of work underway here is in theoretical and practical investigation of cutter vibration. By setting up a vector lag between cutting forces and tool motion on heavy cuts, Russian engineers derive equations that can then be simulated on an analog computer. Stability studies have shown that the cutting tool is stable at high and low speed, but unstable over certain definable middle speeds. All machines being built at this plant are now being checked this way to reduce tool chatter."

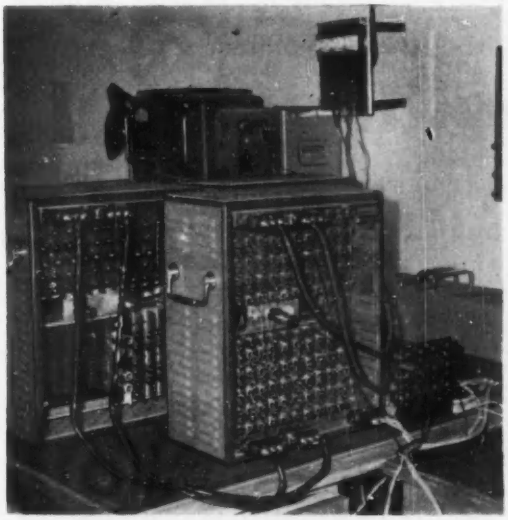
In spite of the magnificent prospects held out at the 21st Congress of the Communist Party and reiterated at last year's plenum meeting, the Russians are apparently not making the kind of progress in mechanizing production operations they would like. But the Soviets have plans to remedy the situation. The Soviet answer is a new institute like the Institute of Automation at Kiev where 2,000 engineers are now at work putting controls to work in industrial applications; by 1965 the Institute will have 6,000 engineers whose jobs will be application and installation of new controls in plants in the Republic of Ukraine. The Soviets plan three similar institutes, one for the Republic of Georgia, one for Armenia, and one for the rest of the USSR.

Since the Kiev Institute bodes to play a prominent role in Soviet productivity in the near future, its current activities are of more than normal interest to western control engineers. Impressed by a visit there, CtE's Derek Barlow had this to say:

"Housed in a brand new building, the Kiev Institute of Automation will eventually consist of six buildings covering 300 acres. Its staff of 2,000 engineers includes technical men at four field stations established in the Ukrainian industrial areas of Zaporodzie, Lisitahansk, Lugansk, and Kharkov. A fifth is under construction at Dneipropetrovsk and will have its own subsidiary operations at Nikopol, Krivoy, Rog, and Dneiprodzerdzinsk.

"Director A. M. Melnik says the institute has set up 40 different laboratories, its own experimental works and plant, and a separate department to convert initial prototype designs into production hardware. Each of the 40 laboratories is concerned with a different manufacturing process and has as an objective the long term study of

HIGHLIGHTS OF THE TOUR



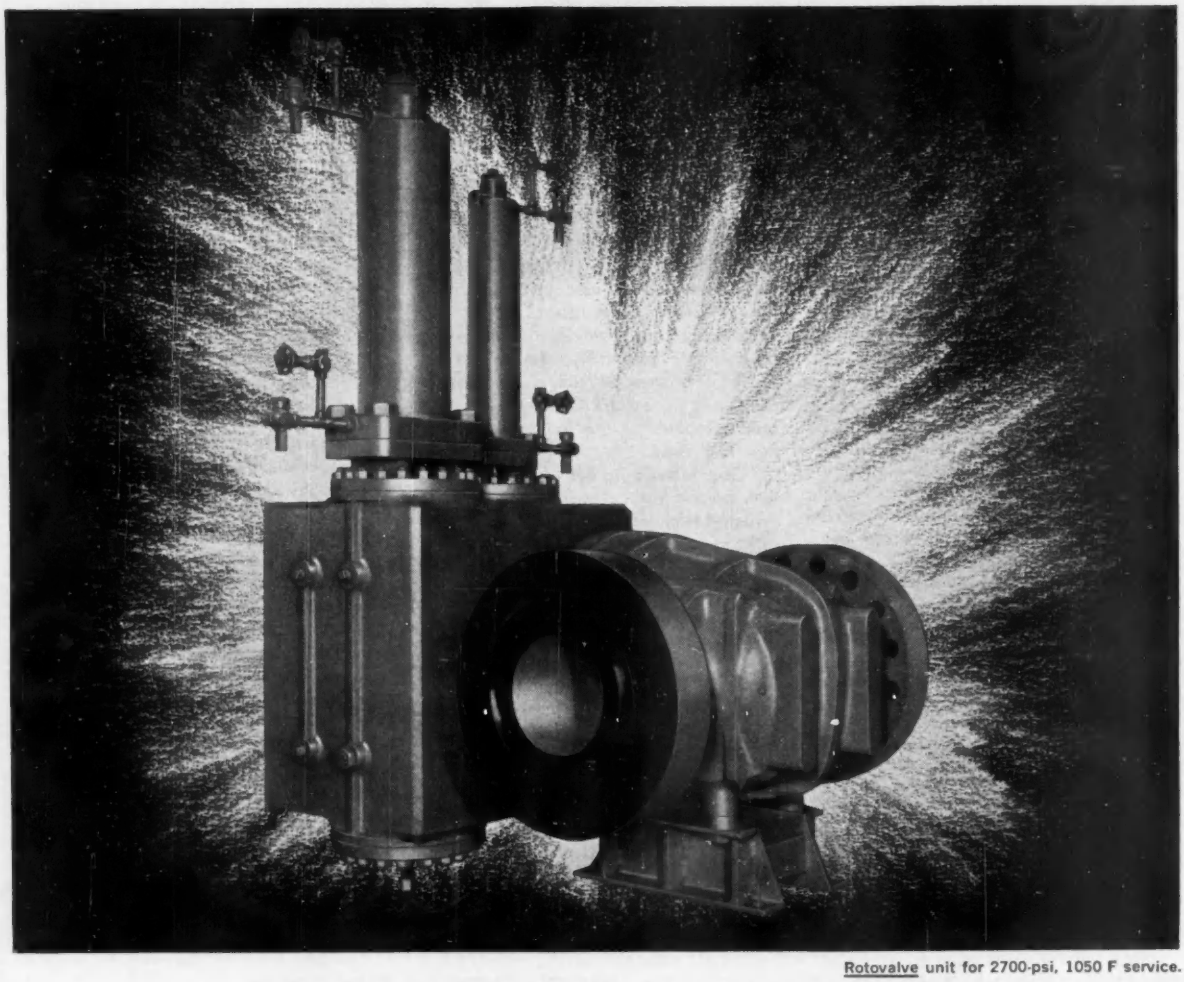
Twelve-variable optimizing control built at the Institute of Automatic and Remote Control.

Magnetic tape storage on a URAL-1 digital computer at the Computation Center of the USSR Academy of Science. The 35-mm coated film carries six channels.



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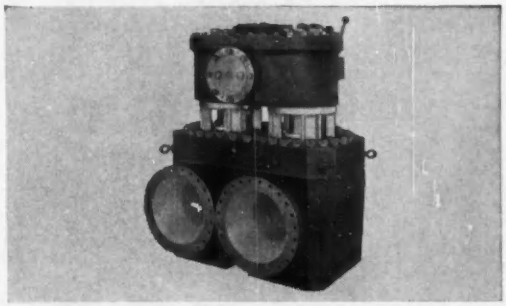
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complex automation of that process. Fifteen plants in the Ukraine are to be brought under complete automatic control by 1965.

"Direction of the institute is effected by the Ukraine State Planning Organization. Plants submit research and development projects to the planning organization, and if the problems are approved, they are forwarded on to the Institute. At present, according to Melnik, the institute has far more requests from plants than it can handle. To pay for this work, the factory making the request supplies part of the necessary funds, and the Ukrainian government provides the rest.

"Here is a rundown reporting some of the current activity at the Kiev Institute:

"Standard panels are being installed to control open hearth furnaces, a technique which has helped the Ukraine bring furnace construction time down to six months. The panels program fuel consumption, oxygen, air flow, and pressures. A simple analog computer calculates heat input to the furnace, and a similar computer determines heat absorption and efficiency to set up optimal heat conditions. At present the computers are turning out operating guides, but sometime next year institute engineers expect to feed the outputs directly into a furnace control. For actual control the Russians employ multipoint on/off electronic control (designated by them P3PI-M6). Up to six variables, on an intermittent cycling basis, can be handled by these controllers.

"The Institute is following the publicized Russian preference for nuclear instrumentation in many processing applications. It also has done some work on ultrasonic measurement techniques. It has, for example, developed an ultrasonic method of determining concentration of a two-chemical solution, with an accuracy of about one percent. Other ultrasonic devices looked quite similar to those used in Great Britain and the United States: for example, a level gage. Among the nuclear instruments the Kiev Institute is applying are a Beta ray thickness gage to measure rubber coating thicknesses at a tire plant, a tank gaging device, a potassium salt analyzer, and a reflection counter.

"In electric power distribution the institute has developed a transistorized analog computer to determine minimum supply cost of power distribution from three generating stations under different distribution losses, incremental costs, and fuel storage limitations. Next step is the linkup of several Soviet power systems into a single grid, a 13-station system. [Editor's note: CtE readers will remember that in the U.S. the Southern Power Co. first did this in 1956—CtE, December '56, p. 77—and it is a common practice today.]

"In another laboratory a digital computer has been developed to program the analysis of aluminum oxide. Receiving measurements of density and conductivity, the computer compares them with information stored in its memory—how these variables change with variations in sodium and aluminum content—to indicate the percentages of sodium and aluminum oxide present.

"Some of the projects are relatively simple. To boost productivity at a coal mine, the Institute has developed a simple system to switch coal dump cars automatically. Digits of a three-digit code are magnetized directly onto a car's steel frame. As it passes a reading head, the code is translated into a control signal that switches the car onto the proper track. An erase head removes the coding when it is no longer required. The coding will stay readable for as long as three days.

"At the Lugansk field station, computer control of plant processes is the main project, but so far it is still in the planning stages. One project under study: automatic flow dispatching in a chemical plant.

"Other Kiev projects range from a continuous contouring system for the flame cutting of ships to an FM two-wire system for transmitting measurements at gas wells on the Ukraine-Moscow pipeline. The contouring system, developed jointly by the Kiev Institute of Automation, the Kiev Computation Center, and a shipbuilding plant, is programmed by 35-mm magnetic tape run through a film projection-type reader which is mounted above a transistorized computer. The first production model is claimed to have an accuracy of plus or minus 0.5 millimeters."

In recapitulating what IFAC visitors saw, some of the most significant deductions are possible by noting what they did not see. The Russians have been notoriously sensitive about what they do not have in all areas—whether it be entertainment, industry, or military. For example, although the Russians talk a lot about computers and obviously have some, they have never permitted any visitors to see their digital computer production facilities. Computer specialists feel that the Russians probably have nothing even close to the giant production facilities of computer makers in Great Britain or the U. S.

Another significant invisibility was computer control. Although last April Dr. A. M. Letov, president of IFAC and deputy head of the Institute of



A. M. Melnik (right) director of the Kiev Institute of Automation poses with a staff member before two artist's conceptions of what the institute will look like in 1965 when it has 6,000 engineers working on the application and installation of automatic controls in industry.

Automatic and Remote Control, assured delegates they would see an installation of computer control at work, the delegates saw nothing resembling it. From conversations with Soviet delegates who attended the IFAC sessions and the Soviet engineers and scientists at the Institutes, IFAC visitors were forced to the conclusion that the Soviet Union still does not have a successful computer control application in a process plant.

Apparently the Soviets are somewhat sensitive about their process industries as a whole. They refused to let the IFAC visitors see a single process plant— despite a persistent request by the British delegation. The Russians also removed from the original tour plan visits to the Moscow Central Laboratory for Automation, the Research Institute of the Power Industry, the Paton Electric Welding Institute, and plants making steam power generating equipment.

Obviously the Russians still show visitors only what they want them to see. As a result a visit to Russia in the summer of 1960 was not such an exciting event for control engineers. They will be able to see much more in the way of new developments next month at a flock of U. S. trade shows.

EDITOR'S NOTE: This story was pieced together from 12 cables filed by CtE's European Editor Derek Barlow. If an item mentioned in the story interests you, additional detail may be in the original cable. Copies of this rough material are available to CtE's readers who ask for it by writing to the Editor, CONTROL ENGINEERING, *330 W. 42nd Street, New York 36, N. Y. Be sure to indicate item of interest.*

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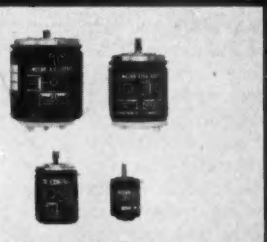
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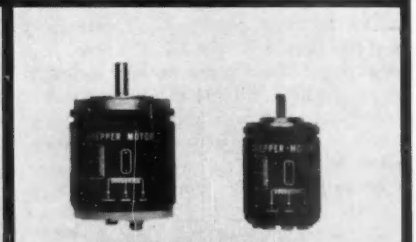
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CONTROL ENGINEER'S GUIDE TO THE 1960 WESCON SESSIONS

	Tuesday	Wednesday	Thursday	Friday
Morning Sessions	**SESSION 1:** Systems and Maintainability **SESSION 4:** Management of Manned Machine Systems **SESSION 5:** Semiconductor Devices and Tubes	**SESSION 11:** Computers — General **SESSION 14:** Analysis of Manned Machine Systems	**SESSION 21:** Component and System Reliability **SESSION 22:** Air Traffic Control **SESSION 24:** Synthesis and Design of Manned Machine Systems **SESSION 25:** Microminiaturization	**SESSION 31:** Seeking a Logical Bioinstrumentation System **SESSION 33:** Information Theory and Modulation Methods **SESSION 34:** Operation and Training of Manned Machine Systems
Afternoon Sessions	**SESSION 7:** Varactors and Tunnel Diode Application **SESSION 8:** Instrumentation **SESSION 10:** Semiconductor Devices	**SESSION 16:** Computer Circuits and Devices **SESSION 17:** Magnetic Data Recording	**SESSION 26:** Government and Industry: Engineering Proposals **SESSION 27:** Air Traffic Control **SESSION 30:** Microminiaturization	**SESSION 36:** Seeking a Logical Bioinstrumentation System (Continued) **SESSION 37:** Coding Methods and Telemetry **SESSION 38:** Information Theory and Modulation Methods (Continued)

Makers Look to WESCON to Perk Up West Coast Sales

LOS ANGELES—To many visitors the 1960 Western Electronic Show and Conventional will be taking place in an atmosphere of cautious watchfulness and waiting. So far this year west coast electronic sales have disappointed some suppliers, particularly component makers who reported that sales have been soft since May. But despite some notes of pessimism, the overall west coast picture is relatively bright.

In January, electronic manufacturers predicted that west coast 1960 sales would run 12 to 17 percent ahead of 1959. In the first six months of this year, the sales increase has just about kept pace with the lower estimate. Market experts feel that regional sales growth might have reached the maximum predicted if component sales had not turned down.

What's behind the sag in these is what has made electronics men anxious. One reason offered often is the impact of Japanese semiconductors which are starting to be used in greater quantities. Another is that some large users of components have launched large scale cost-cutting programs along with personnel shakeups, so that a lot of regular buying is being postponed or forgotten. Still another reason is that the uncertainty in Dept. of Defense policies is holding off buying by some prime contractors on military projects.

Component makers are hoping that the excitement and enthusiasm of a well attended WESCON will help turn the tide. This year's show, to be held August 23 to 26, will fill two levels of Los Angeles' new Memorial Sports Arena with 987 exhibits. A technical conclave with 40 sessions is being held concurrently with the show. Sessions of prime interest to control engineers are summarized in the chart above. Session numbers are those assigned by WESCON.

Three key areas are dominating the program from a control engineer's viewpoint. They are: Manned Machine Systems, Components, and Bioinstrumentation.

In the manned machine systems area four separate sessions have been planned, each to cover a different part of the problem. One session is tackling the management of such systems, another the analysis of the manned machine system, a third, synthesis and design, and the last, operation and training of the systems. Speakers will include representatives of the military, industry, and academic researchers.

The key role of electronic components is reflected by six sessions planned for users. Three sessions will be devoted to reports of new semiconductor and tube devices, and one of these will be solely allotted to discussions of varactors and tunnel diodes. Another session will consider the peripatetic problem of component and system reliability, and two sessions will hear approaches to microminiaturization.

Bioinstrumentation systems are relatively new on the control engineer's horizon. There has been speculation about such systems for several years, but it is only recently that hardware has started to appear in large quantities, proving or disproving some of the theoretical ideas expounded by psychologists and medical men. Objectives of such work have several different directions. In one, researchers are interested in devising instrumentation to measure physiological variables for such programs as the Man in Space Project. In another, researchers are attempting to build bioinstrumentation that can be used for diagnostic or therapeutic purposes. Both areas will be covered at the WESCON sessions.



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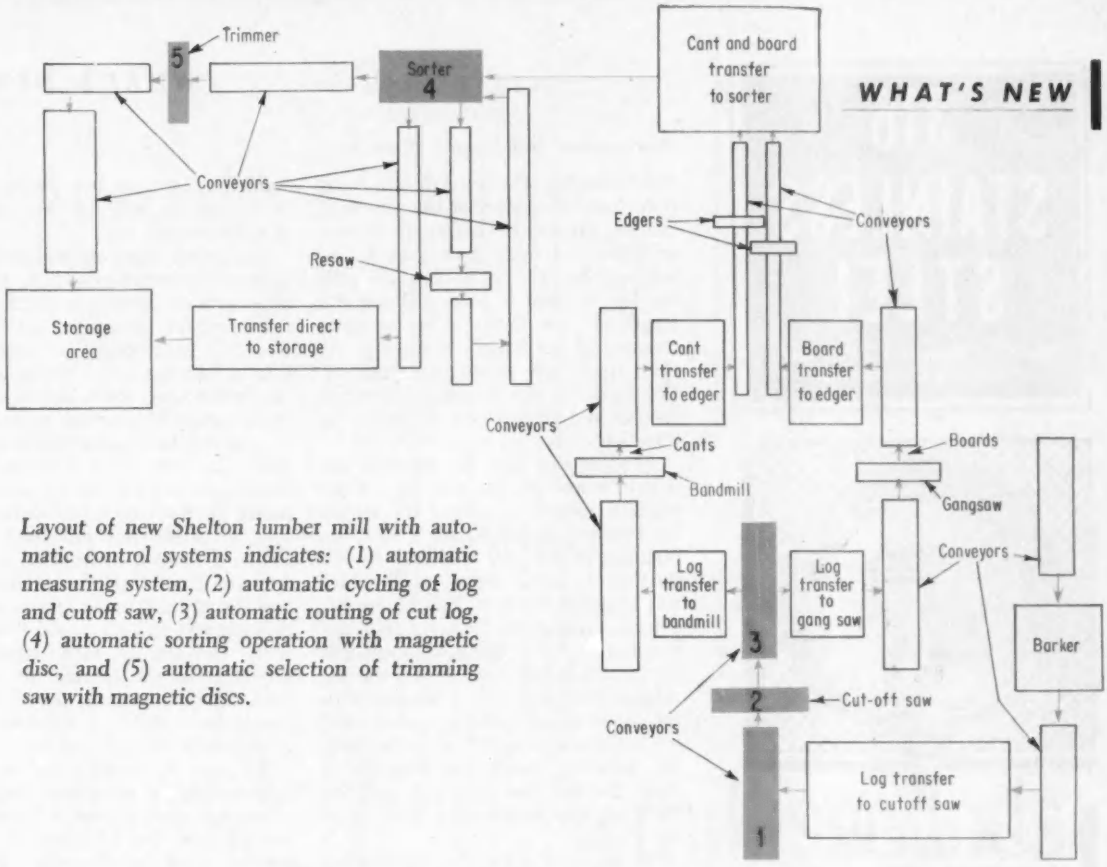
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Layout of new Shelton lumber mill with automatic control systems indicates: (1) automatic measuring system, (2) automatic cycling of log and cutoff saw, (3) automatic routing of cut log, (4) automatic sorting operation with magnetic disc, and (5) automatic selection of trimming saw with magnetic discs.

Magnetic Discs Add Automatic Control to Lumber Mill

Automatic controls going into a Washington lumber mill may mark a new era in the lumbering industry, which has not had many automatic operations before.

SEATTLE, WASH.—In the lumber industry, better known for its robust woodsmen than its modern equipment, automatic operations are few and hard to find. A new $1 million small-log sawmill now being built for the Simpson Logging Co. at Shelton, Wash., may change all that. When it starts operating this autumn, the new mill will be the closest thing to an automatic plant in the lumber industry. System design was performed by the consulting engineering firm of Tracey, Cook, Brunstrom and Dudley.

With the help of automatic controls, the mill's 17-man crew will produce 120,000 board ft of lumber in one 8-hr shift. That means 7,000 ft per man—better than anything else in the industry and more than twice the industry average.

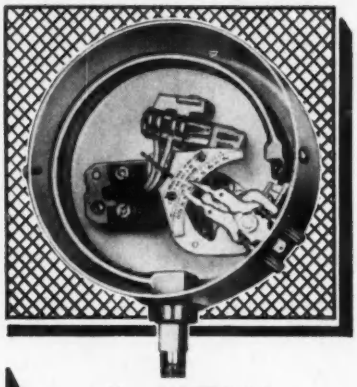
A small-log sawmill is unusual in itself. It has been designed to handle economically those small logs that most mills have to reject. Actually the Shelton mill has considerable flexibility. It will be able to process logs from 6 to 30 in. in diameter in lengths from 10 to 42 ft.

Processing starts with removing the bark. The log is cut into shorter lengths and its ends squared by a cutoff saw. These lengths are cut into thick rectangular slabs called cants or are turned into boards of desired thickness by a gang saw. After squaring in edgers, the boards and cants are cut to size by a trim saw into lengths to bring the best prices. Then the finished products are sorted and carried out to a yard for storage.

• **Automatic measuring**—The first key point of control is at the cutoff saw where the debarked log is cut into lengths of 10 to 26 ft. With shorter logs this operation consists only of squaring the ends which were rough-cut in the forest. But most logs are cut into at least two lengths. In the Shelton mill an automatic measuring system will determine where to make the cuts instead of relying on the judgment of the operator as conventional mills do.

An overhead trolley which is pulled back and forth by a cable is the main component of the measuring system. Here is how the measuring device works. As a log is placed on the conveyor leading to the cutoff saw, it cuts a beam from a photocell activating the trolley. This action causes an arm from the trolley to drop down and strike the lead end of the log. The arm then pivots up and lies along the log as the trolley moves toward the far

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New Lumber Mill Control (Cont.)

end of the log at a speed of 600 ft per min. Loss of contact of the arm with the log causes the trolley to reverse until the arm finds the log again. As long as the arm is in contact with the log, a signal is generated and the length of the signal is an accurate measure of the length of the log. At the cutoff saw operator's position, this signal is continuously converted to feet and inches and displayed on a readout dial.

Reading this dial, the operator can decide where to cut the log. Then controls take over again. He might, for example, decide to cut a 42-ft log into two lengths, 20 ft and 18 ft. To do this, he would merely push a button assigned to 20-ft lengths on his console. Along the conveyor that carries the log past the saw, photocells are located every 2 ft. When the log reaches the photocell associated with the signal inserted at the console, the log is slowed, stopped, and clamped, the whirling cutoff saw lowered to make the cut and retracted, and the sawn log unclamped—in a 5-sec automatic cycle.

At the same time the operator selects the length he wants the log cut to, he also presses a second button to automatically route the cut log to the next process: the band mill which reduces the logs to cants, or the gang mill which reduces the log to boards. Then both move to edgers and on to the trim saw to be reduced to the most economic lengths.

• **Using magnetic memories**—The next key point of control is at the trim saw, where the trimmer operator cuts the boards into lengths which will command the best prices. If the 18-ft log produced by the operation described above were to include 10 ft of high priced clear lumber and 8 ft of lower priced knotty lumber, the trimmer operator would cut boards from that log into two pieces instead of having the mill sell the one piece at a discounted rate.

Automatic controls will make the trimmer operator's job easier. First off, all lengths are already in multiples of 2 ft because of the control on the cutoff saw. In addition, a mechanized sorting system located before the trim saw will relieve the trimmer operator of considerable decision making.

A sorting table, on which the boards move at a rate of 90 ft per min, has been built, and a sorter operator is stationed in front of a pushbutton console to direct the incoming board. When a board is in front of him, the operator decides whether it should bypass the trimmer and continue directly to a conveyor which would then carry it to the storage yard, whether it should go to the trimmer for cutting into different lengths, or whether it should be carried to a resaw to be upgraded into thinner boards.

To carry out his decision, the sorter operator pushes a button which puts a magnetic spot on one of three memory discs of the Magnestat memory system, built by Republic Electric and Development Co. As the disc rotates, the spot moves to a solenoid, actuates it to open the proper gate to move the board onto the correct conveyor line. As the disc completes its rotation, it passes an erase coil which removes the magnetized spot.

With a similar memory system the trimmer operator controls the operation of 14 saws, mounted at 2-ft intervals. After he has determined the proper length to cut the finished piece, he pushes a button, creating a magnetic spot on one of the 14 discs corresponding to the saw he has chosen. Then the cut boards are moved out into the yard for storage.

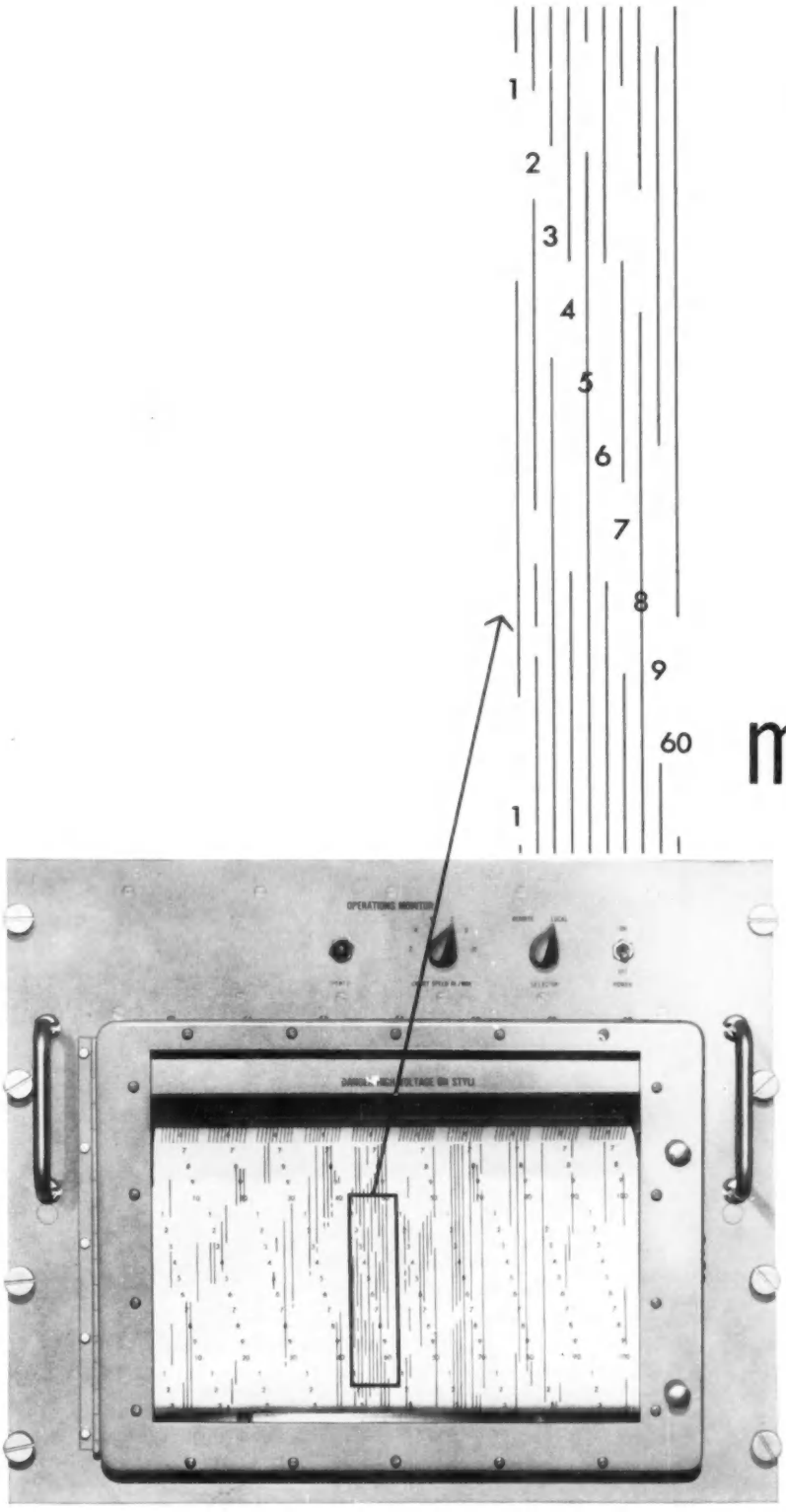
—Ray Bloomberg
McGraw-Hill News

Precision Measurement for Canaveral Missilemen

NEW YORK—By January 1962 the Air Force Missile Test Center at Cape Canaveral will have in operation a new precision tracking system called MISTRAM for Missile Trajectory Measurement System. It will place vehicles in space with an accuracy 10 to 1,000 times better than the best instruments currently in use at the Cape.

Developed by the Defense Systems Dept. of General Electric, MISTRAM is an interferometer technique which owes its high precision to long base lines—100,000 ft. in the Florida installation—and a unique approach to ambiguity resolution of phase difference.

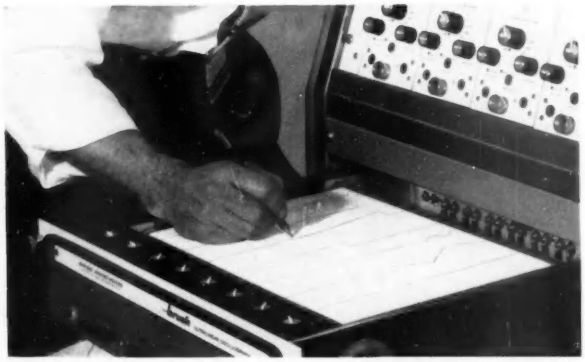
Information from the tracking system will be converted to computer format and fed directly into the Cape's IBM 709 so that test engineers and the range safety officer will have real-time position data. Cost of the AFMTC installation is estimated at $15.5 million.

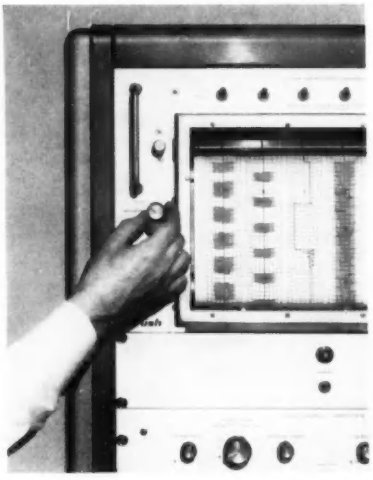


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Australia Inventories Its Data Processing Prospects

Australian computer specialists and enthusiasts held the first Australian Conference on Automatic Computing and Data Processing in May. A roundup of what's happening in data processing down under indicates a boom is on the way.

SYDNEY, AUSTRALIA—Electronic general purpose digital computers are coming of age in Australia. At the First Australian Conference on Automatic Computing and Data Processing held here, a variety of companies in many different industries indicated that they are now ready to accept electronic computers as a general purpose tool. Even with this enthusiasm Australia is about three years behind the U.S. and Great Britain in data processing application. There are 28 computers in Australia now; 35 more are on order to be delivered within the next 12 months—all 63 will be imported.

Just how wide is the interest in computers can be seen by the groups who cooperated in the conference. The meeting was organized by the Australian National Committee on Computation and Automatic Control, a group formed in April 1959 by such societies as the Actuarial Society of Australasia, the Australasian Institute of Cost Accountants, the Australian Institute of Management, Australian Society of Accountants, the Institute of Chartered Accountants in Australia, the Institute of Physics—Australian Branch, the Institute of Engineers (Australia), the Royal Australian Chemical Institute, and the Statistical Society of New South Wales.

• **Aussie applications**—Leading in commercial data processing is the insurance industry. For example, two Sydney companies have installed IBM 650 machines. First to put checks on punched cards and to use computers to process them was the Government Social Services. And the Australian Gas Light Co. is using an IBM 650 for both scientific problem solving and accounting. With the computer the gas company's operation research team has studied mathematical models of the production process and the distribution of gas throughout the Sidney area. As a result of the study, the company has rearranged its production, saving the cost of the machine in its first month of installation.

All these installations have been with medium sized computers. But the Australians are bringing in some big ones too. The Australian government has just signed an agreement to rent an IBM 7090 for scientific problem solving at the Weapons Research Establishment at Salisbury, South Australia. The machine will be installed early in 1961 to solve missile range and space research problems.

• **Applications in progress**—The scope of projects underway indicates that Australia will be a big user of computers in the future. For example, the government is preparing a weather study to be solved on a computer with the object of bringing drought relief to Australia's northern state of Queensland. Another investigation is aimed at determining the volume of usable lumber in forests of pinus radiata.

In the area of chemical engineering, multicomponent distillation column design is about to be speeded up with computer help. Other areas that are now experiencing their first encounter with computers: hydroelectric engineering, computing methods for trim scheduling in the paper industry, rural road design, and banking.

• **Equipment just starting**—Australian designed computers are still in their infancy, practically all the work being done at colleges. The first Australian designed machine was built by the Commonwealth Scientific and Industrial Research Organization. A second machine, called SIRAC, is now at the University of Melbourne, and although it is still in use, the Aussies are not particularly proud of it. It is relatively slow, has both mercury delay line and magnetic drum memories. The Electrical Engineering Dept. at the University of Sydney has built a digital differential analyzer, an improved version of which is to be built by the Snowy River Authority. The University of Sydney has also built SILLIAC, an Australian version of the machine designed at the University of Illinois.

—Elizabeth Fisher
McGraw-Hill World News

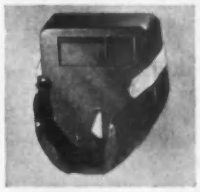
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... for positive retention in all mobile applications

There's no jump, no sway—when a telephone handset is in the firm grip of this new handset cradle by Stromberg-Carlson.

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The cradle is strong and resilient, fits any Stromberg-Carlson handset. Different models provide varying switch combinations with 2 or 4 Form C contacts. All models available with or without the clip assembly.

Specifications on request. In Atlanta call TRinity 5-7467; Chicago: STate 2-4235; Kansas City: HArrison 1-6618; Rochester: HUbbard 2-2200; San Francisco: OXford 7-3630. Or write to Telecommunication Industrial Sales, 112 Carlson Road, Rochester 3, New York.

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AiResearch Manufacturing Division

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TV and Microphones Monitor Cement Plant

TORONTO, ONT.—

The crusher operator at the St. Lawrence Cement Company monitors production by eye and ear as the Clarks (Ontario) plant turns out 20,000,000 bags of cement a year. A closed TV system and a complicated listening system with microphones at key points in the plant enable an operator to keep tabs on production from a console.

On three TV monitors the operator watches the bins into which trucks dump sand, gravel, and cement rock; the chutes from the bins showing how the material is flowing to the production lines; and the conveyor belts that carry materials to the processing gear.

The microphones pick up vibration of the grinding operation. Since grinding of the maximum load with proper materials produces a certain vibration, any variation from that vibration means the plant is not operating at optimum. The microphones pick up the vibrations and pass them into a special purpose electronic computer where they are compared to a standard, and the output is a control signal that tries to bring the mill back to optimum operating conditions.

Iron Curtain Technical Aid Needs British Instruments

LONDON—

When Rumania announced it was supervising construction of the Gauhati (India) 15,000 barrel per day refinery, questions were asked as to where the Rumanians would get the instrument and control know-how. The answer came last month when Elliot Automation Ltd. announced an $840,000 contract for instrumentation at the $43 million refinery.

Placed by the Rumanian Techno-Import of Bucharest, the order is the most comprehensive of its kind ever received by Elliot. Rumania made the contact through Elliot's Swiss subsidiary. Shipments just started.

Commerce Translates Russian Technical Journals

WASHINGTON—

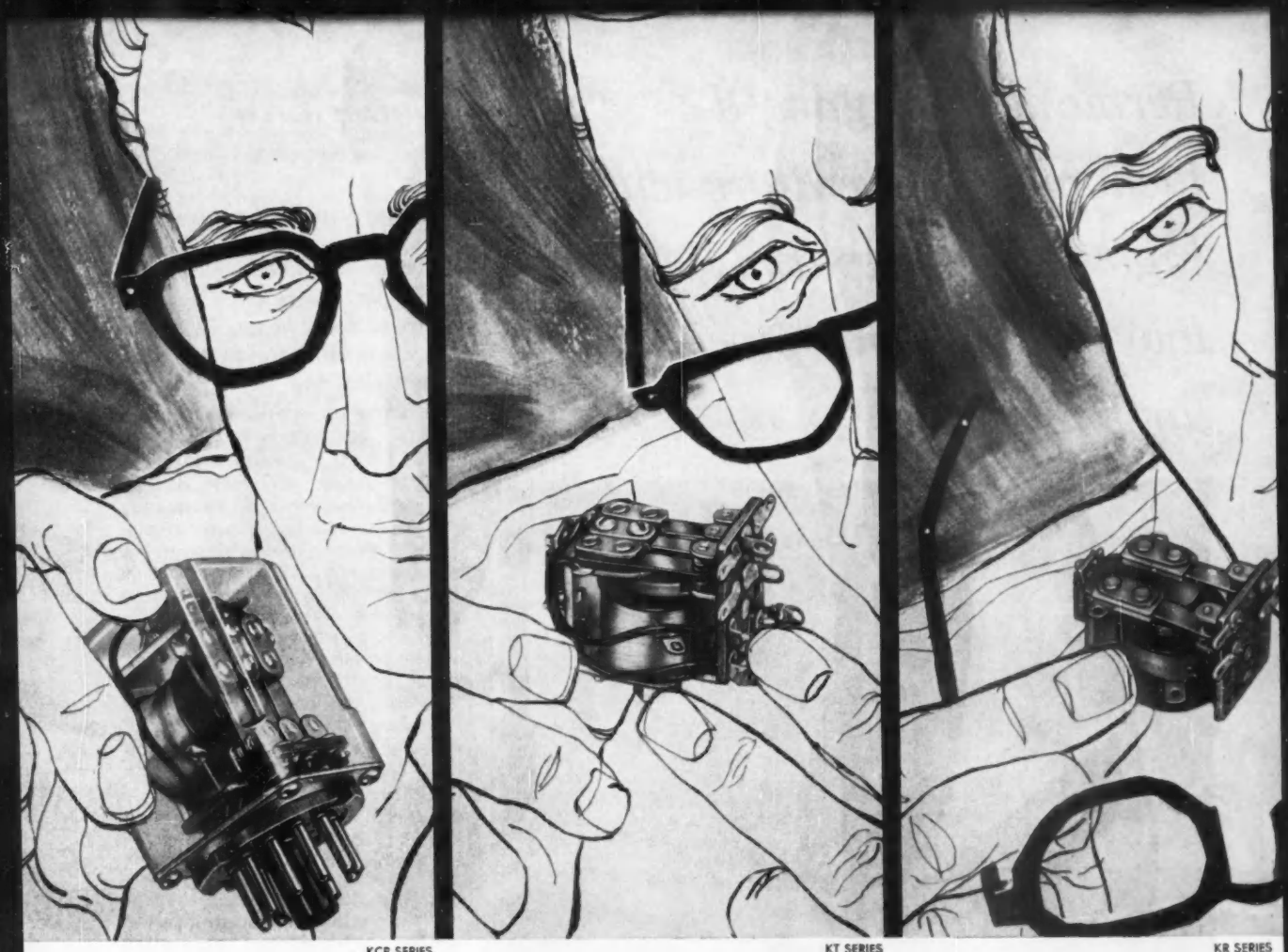
U. S. Department of Commerce's Office of Technical Services has underway publication of *Current Review of the Soviet Technical Press* on a weekly basis. The new service contains translations and reviews of scientific and technical articles appearing in Soviet publications.

Cost of a subscription is $7 for six months. Subscriptions should be addressed to U. S. Dept. of Commerce, Office of Technical Services, Washington 25, D. C.

Optical Maser Concept Demonstrated

The amplification of light by a device similar to the microwave maser was demonstrated last month by scientists of the research laboratory of the Hughes Aircraft Co. Called a laser, for Light Amplification by Stimulated Emission of Radiation, the device (right) consists primarily of a ruby crystal shaped into a cylindrical rod and surrounded by a photoflash tube. A flash of the tube raises the energy level of molecules in the ruby; when they return to zero or ground state, they radiate energy in the visible spectrum—red light of 6943 Angstrom wave length. The excited atoms are coupled to an optical resonator and stimulated to emit the radiation together. Unlike microwave masers the device does not require a magnetic field or low temperature for operation. Light emitted by the laser is practically of a single wavelength (coherent) and radiates in almost a parallel beam.





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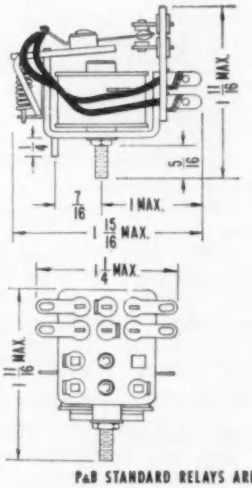
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Many design engineers find it saves time, saves money to integrate their circuits with *related* P&B relays. Makes sense, doesn't it?

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KT—Designed for antenna switching. Capacitance: 0.5 mmfds between contacts. Terminal board is glass melamine and stack insulation is glass silicone for minimum RF losses to switch 300 ohm antenna line. 3 PDT max. AC or DC.

KC—Low cost plate circuit relay with sensitivity of 125 mw per pole. Factory adjusted to pull-in on specific current values. Available open, hermetically sealed or in clear plastic dust cover with standard octal-type plug. 3 PDT max. DC.



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Temperature Range:
DC Coils—45°C to 85°C.
AC Coils—45°C to 70°C.

Terminals:
Pierced solder lugs standard. Octal 8 and 11 pin plug-in headers available.

Enclosures: Type K—Hermetically sealed.
Type P clear cellulose acetate dust cover.

CONTACTS:
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Material: ⅛" dia. fine silver (gold plated).
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Load: 5 amperes 115V 60 cycle resistive.

COILS:
Resistance: 16,500 ohms max. AC or DC.

Power: 1.1 watts minimum to 4 watts maximum for DC at 25°C ambient.

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Insulation: Centrifically impregnated with insulating varnish.

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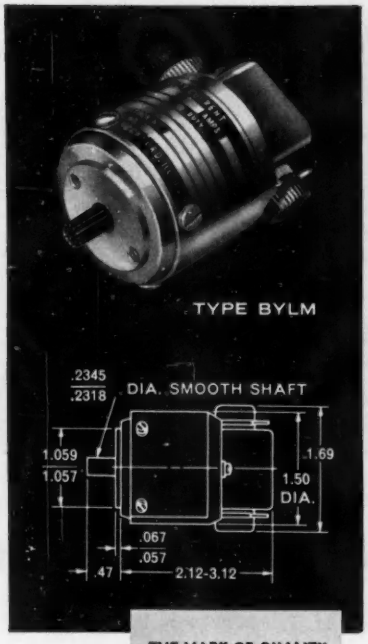
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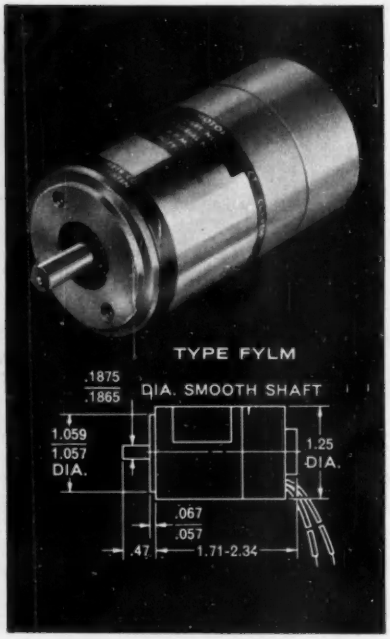
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WHAT'S NEW

Aping Man On Computers

Human simulation is mushrooming, the aviation conference of ASME hears. The payout may be improved medical treatment and better understanding of adaptive systems.

DALLAS—

To exponents of simulation techniques, the ultimate is duplicating the action of a human being on a computer. Once a fanciful idea, human simulation now looms as the newest tool in man-machine research, one so important that over half a dozen technical papers were presented on the subject at the aviation conference of the American Society of Mechanical Engineers last month. The speakers envisioned broad strides in medical diagnosis and human operator models in the next few years. Some eye-opening predictions:

- Diagnosis of pathological conditions by reproducing symptoms on a simulator.
- Duplicating little understood phenomena in the human system so scientists can study the mechanisms.
- Developing, through simulation, procedures and techniques for treating the human being.
- Optimizing the design of equipment that a human must operate by simulating the human's performance with real or simulated machinery.
- Building superhuman devices with simulated human capabilities as a foundation.

How fast computer men can make such predictions come true depends somewhat on the funds available and some more on computer development. But human simulation work has been mushrooming at a startling rate. North American Aviation's A. Ben Clymer reported that the amount of work in the field has doubled every two years for the last 10. He predicts it will continue to grow at that rate—or faster—for the next 10 years.

One accomplishment that is close is the simulation of interacting homeostatic systems, body systems that automatically stabilize levels of oxygen, temperature, alkalinity, etc. Simulation of cells has already been performed; simulation of the homeostatic systems could be a big help in surgery, pathology, and pharmacology.

Another area under intensive study is the complete simulation of a hu-

man operator. The objective: to define a model that will display such man-like conduct as intermittent attention and behavior and explicit decision making and planning ability. Such a model might predict, for example, how a human pilot would react to an instrument display in the cockpit before the cockpit design was frozen, thus cutting out much of the trial and error design which is standard practice.

• **Finding a model**—What the model might look like was the subject of some farsighted musing by North American's Clymer. He first cited some of what the model would *not* resemble. For example, transfer functions, currently used in such simulations, are not adequate. They do not accurately represent a human operator's behavior, because they are not general enough in applicability, and because they do not contain an explicit representation of the functional organization of the human operator. A model that consists of a network of linear and nonlinear continuous analog-computer components is not the complete answer either because it is a continuous model whereas the human operator is known to be markedly discontinuous.

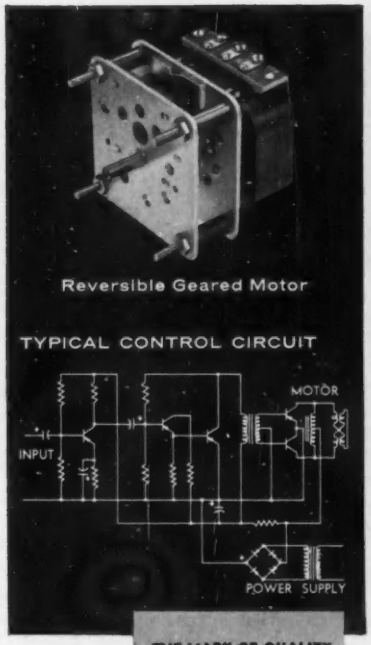
For a more comprehensive and realistic simulation, he said, the model must incorporate five interacting functions: neuromuscular, plan generating, decision-making, error predicting, and perceptual systems. And some of the interactions between the operator's psychophysiological processes and his task-oriented activities should be incorporated.

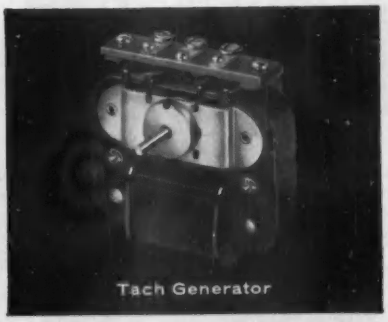
• **Accent on medicine**—As a review of what's been happening in human simulation, Clymer's presentation set the stage for papers that followed. A. J. Gold, General Electric Missile and Space Vehicle Dept., urged the simulation of homeostatic systems as a means for supplying control engineers with some new relationships for adaptive controls. He described in detail the system which the body uses to keep acid and alkalinity balanced, noting that it is a self-adapting biological system.

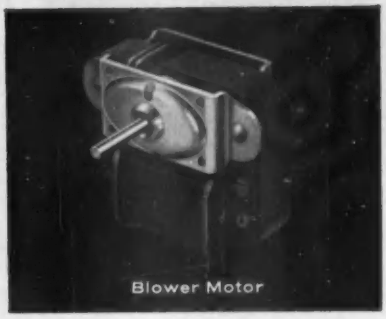
In a review of successful medical simulations, Ohio State University researchers Ralph W. Stacy and Norman A. Coulter, Jr., speculated on the use of simulation for medical diagnosis. This simulator would be a digital computer, programmed so that it duplicates the examination, comparison, and evaluation of medical data the same way a diagnostician might. One program has already been written to perform the differential diagnosis of blood diseases.

—Marvin Reid
McGraw-Hill News

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Defense Control Grows Faster Than Military Budget

Sperry planning expert also sees even bigger lag for industrial control but forecasts eventual application of many military advances.

The electronics—and control—portion of defense spending is growing 10 times faster than the military market. That is the conclusion of John J. Rutherford, Director of Long Range Planning, Sperry Gyroscope Co., Div. of Sperry Rand Corp. Reviewing the growth of electronic instrumentation and control before the annual convention of National Federation of Financial Security Analysts Society, Rutherford observed that while the total military budget increased 15 percent from 1953 to 1960, the electronic-control portion has grown 150 percent, from $2.5 billion in 1953 to over $6 billion in 1960.

In addition, the electronics industry has more than doubled its share of the defense budget, taking about 15 percent of defense spending last year, versus seven percent in 1955. In a few weapon systems, instrumentation and control represent nearly 50 percent of the total cost. Assuming a continuation of growth at this rate, Rutherford predicted that electronics would account for 20 cents out of every defense dollar by 1970.

• **It's catching**—Some of the new technology developed for the military is being picked up by industrial users. From a technological standpoint, military applications still lead industrial applications in sophistication. One estimate: industry lags the military in application by about six years.

Ten years ago, the Sperry executive said, electronics represented less than two percent of industrial equipment purchases. Last year this figure hit over six percent. And there are some indications that industrial use of electronics is likely to grow even faster.

• **Butter and guns**—One factor increasing military suppliers' interest in industrial markets is the unreliability of defense contracts. A change in tactics or policy can wipe out an entire project, something over which the supplier has little control. Any reduction in military spending—probably as the result of a lessening in world tensions—will increase the incentive for the defense electronic industry to develop industrial markets, says Rutherford. On the other hand, an expansion in military electronics needs will limit the amount of facilities available for industrial developments.

Rutherford went on to spell out the areas of commercial or industrial applications of prime interest to military electronics companies. Aircraft has up to now been the major consumer of military dollars, and 25 percent of the price tag is for electronic gear. Air traffic controls have been borrowed from military developments, and techniques derived from in-the-air bomber refueling and all weather landing will ultimately contribute to commercial aviation, according to the Sperry planning expert.

Missiles will soon be the leader in defense spending, and electronics currently takes up to 50 percent of the total. The navigation and guidance systems developed for tactical and strategic vehicles have contributed to space exploration programs. And just as important, Rutherford asserted, the new concepts in computers developed for the missile effort have provided significant solutions and cost savings for business problems.

Precise navigation, search, detection, and tracking systems have already provided welcome products for the commercial market. And even small boat owners can use radar for navigation and sonar techniques for spotting good fishing waters.

Air defense techniques have contributed to the automatic data processing art and have spawned new commercial developments in automatic telephone systems and microwave data link networks. And space research can be expected to contribute major medical benefits.

Ampex, TMI Engaged In Merger Negotiations

SAN FRANCISCO—A merger of Ampex Corp., Redwood City, Calif., and Telemeter Magnetics, Inc., Culver City, Calif., is under consideration, the company presidents announced last month. The tieup would be on the basis of two shares of TMI for each of Ampex, with Ampex as the surviving company.

Ampex is the nation's leading mag-





Just as Philadelphians read the Bulletin, electrical engineers read the General Radio *Experimenter*. Published monthly and sent without charge to 130,000 engineers, scientists, and technicians, the *Experimenter* features articles written by engineers for engineers.

In the *Experimenter's* pages you'll find descriptions of new G-R products, details of electronic measuring techniques, tips on how to get more use out of your test equipment, and accounts of interesting and unusual measurements problems and their solutions.

Many informative articles are scheduled for the *Experimenter's* pages, including: details of a new high-speed stroboscope; a discussion of the characteristics of tunnel diodes at ultra-high frequencies; and an announcement of a new Frequency Meter and F-M Discriminator that will measure from a few cycles to 1.5 Mc with ¼% accuracy. This new instrument is also capable of measuring one part-per-million of incidental fm.

If you would like to receive the *Experimenter* and keep up with new developments such as these, fill out the coupon at the right and send it to us. We will see that your request is processed promptly.

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Engineering notes from the **SM/I REPORTER**

BY STANLEY M. INGERSOLL, *Capabilities Engineer*

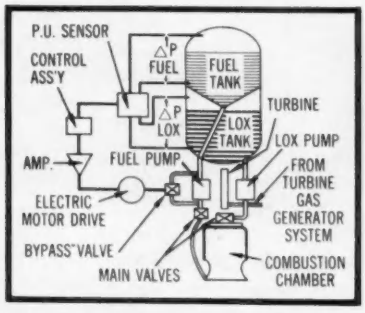


Report No. 10
AQC 600 Propellant Utilization Control System

For maximum efficiency from a liquid propellant missile, fuel and oxidizer must be depleted simultaneously. Our new AQC 600 system, which consists of a controller and a differential pressure ratio sensor, measures the pressure ratio of fuel and liquid oxygen remaining in the tanks of a missile at any given time – then accurately controls the flow of these propellants into the combustion chamber. The percentage of accuracy is based on the propellants remaining in each tank, not on the full scale quantity. This reduces the absolute error signal as the propellant levels are decreased. The SM/I system measures the liquid head of each propellant and computes the ratio between the two head pressures electromechanically. An amplified error signal actuates a valve that changes the relative flow between fuel and liquid oxygen until the error signal is reduced to zero.

Typical Performance Specifications

Pressure Conditions		
Max. line pressure	120 psig	
Max. differential pressure	35 psid	
Min. differential pressure	0.2 psid	
Ambient	0-15 psi	
Gaseous medium	Gox, Helium, N_2, Air or H_2	
Electrical		
Input	115 volts, 400 cps, 10W 28 VDC – 1 amp.	
Heater Voltage (used only below 35°F)	28 VDC – 30 watts	
Environment		
Vibration	10-38 cps ±20 g's 38-2000 cps ±20 g's	
Shock	30 g's	
Acceleration	15 g's (one axis)	
Accuracy (on basis of ratio)		
Sensor ..... ±0.5%	Computer...±0.15%	
Weight		
Sensor ..... 3.8 lb	Controller...4.8 lb	





Photograph and over-all system diagram

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WHAT'S NEW

netic recording equipment manufacturer, had sales for the fiscal year ending April 30 of $68.1 million. TMI is a maker of magnetic core elements, memories, and other similar components; the firm had sales of $4.6 million in 1959.

At the latest word, negotiations were still in progress, and the companies refused to comment on the prospects for success or on a timetable for completion of the talks, director approval, and stockholder action.

AF Sets Up Aerospace Corp., Successor to STL

INGLEWOOD, CALIF.—

The nagging problem of what to do about Space Technology Laboratories, Inc., the Air Force's manager for missile and space programs, has finally been resolved with the formation near Los Angeles of the Aerospace Corp. The Air Force has set up the unit as a nonprofit, multimillion dollar civilian agency to take over gradually STL's far-reaching responsibilities.

STL has been a bone of contention among missile contractors since it was first set up as a systems manager. Other contractors resented STL's role as program manager and prime contractor. Congress was concerned over such a large and vital piece of the defense pie being held by one contractor. USAF, losing interest in the all-in-one-hat weapons system manager concept anyway, was inclined to agree with its critics for once.

Not even STL and its parent company, Thompson Ramo Wooldridge, Inc., have been happy with the setup because of their inability to compete for other business because of their singular position.

Aerospace Corp.'s first major tasks will be management of the Discoverer, Midas, and Samos satellite programs. STL will retain direction of the Atlas, Titan, and Minuteman ICBM programs, already well advanced.

The new corporation was set up based on the recommendations of studies initiated by the Air Force, results of Congressional inquiries, and, most important, the report of the Air Force sponsored committee of scientists and industrialists headed by Dr. Clark Millikan of Cal Tech. Aerospace will eventually move into several buildings of STL's El Segundo, Calif., plant and will offer jobs to key personnel from STL.

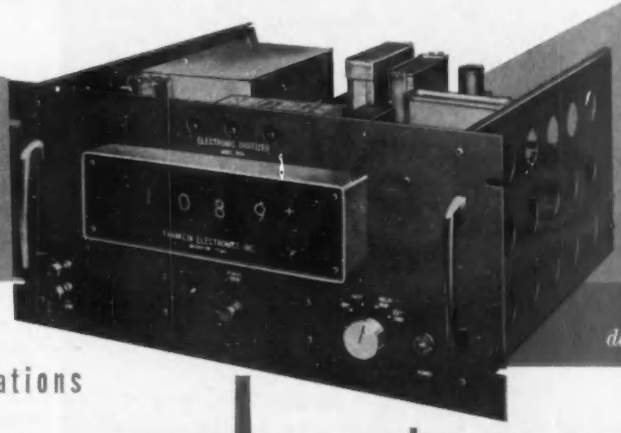
Aerospace was set up without capital stock; it is operating under an AF

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There's never any need for exasperating knob twiddling with a Franklin Model 1310N. Magic? No, just plain practical design. All operating potentials, including the line voltage, are regulated before they're put to work. What's more, there are no stepping switches, relays or other mechanical components to introduce noise or delays . . . it's all-electronic for whisper-smooth voltage conversion . . . and with a stability never before equalled. The brief specs tell more.



MODEL 1310N, ALL ELECTRONIC ANALOG-TO-DIGITAL CONVERTER/VOLTMETER..... $2090*

request data sheet 2006

brief specifications

RANGES:	000.0 to 120.0 V dc. Input sensitivity: 0.1 V per digit. Matching amplifiers are available with minimum ranges of 1 mv per digit or 100 uv per digit.
RANGE AND POLARITY SWITCHING:	Optional automatic or manual (with amplifier).
ACCURACY (ABSOLUTE):	± one count (± 0.1% of full scale) after 10-minute warmup.
STABILITY:	Absolute accuracy is maintained for at least one year without calibration.

INPUT IMPEDANCE:	100 megohms.
READOUT TIME:	Maximum of 12.2 milliseconds to 120.0 volts full scale.
SPEED:	Up to 40 readings per second.
POWER:	100—125 V, 60 cps, 200 watts.
DIMENSIONS:	19" rack panel unit, 8¾" H x 15" D.
WEIGHT:	Approximately 50 pounds.

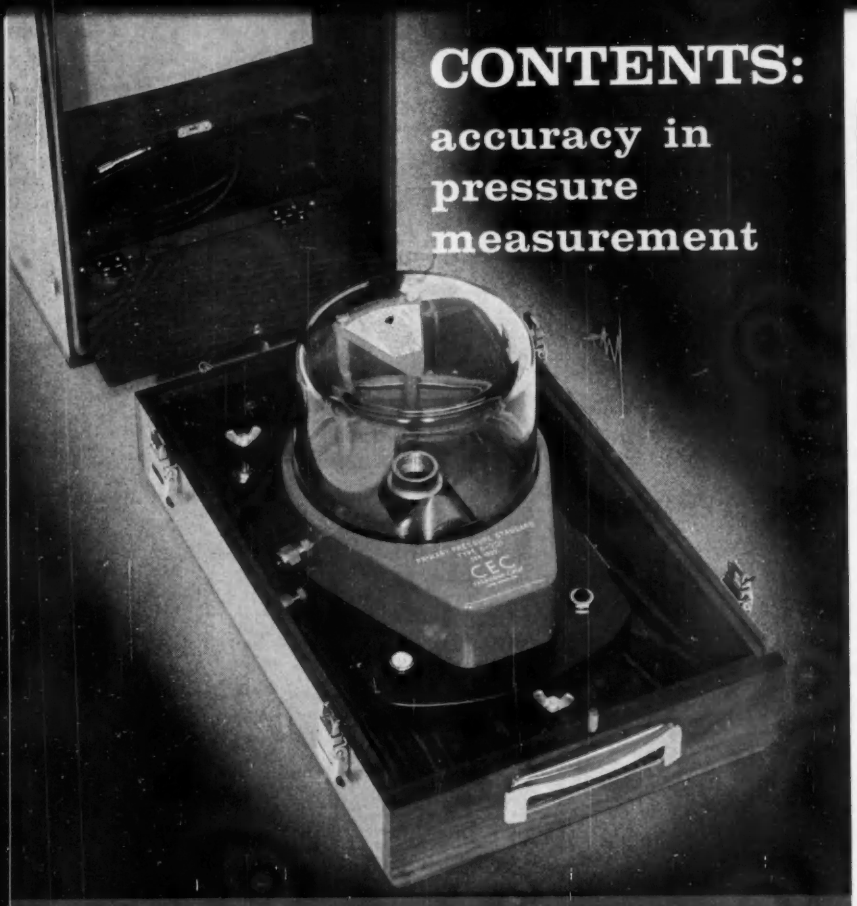
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Here's the starting point for precision calibration of pressure measuring instruments... here's where accuracy begins. It's CEC's portable 6-201 Primary Pressure Standard, a pneumatic dead-weight piston gage that assures resolution of 0.005% of reading.

This lightweight instrument is so simple to operate that its accuracy of gage and absolute calibrations is all but independent of operator technique.

The 6-201 covers six pressure ranges between 0.3 and 500 psi, with accuracy of 0.015% of full scale in the 1.5, 5.0, 15 and 50 psi ranges and 0.025% of full scale in pressure ranges of 150 and 500 psi.

Because the 6-201 relies only on fundamental dimensions for measurements, it is independent of any other instrument for its calibration. It uses mass, length and time for its references.



For complete information on the 6-201, write for Bulletin CEC 1581B-X27. For data on CEC's integrated line of instrumentation and pressure measurement devices, ask for Bulletin CEC 1308-X17.

Transducer Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

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WHAT'S NEW

account placed by some observers at $5 million. Heading its board of trustees is Roswell L. Gilpatrick, former Air Force under secretary. Set to become the company's president on August 1 is Dr. Ivan A. Getting who has been vice-president for engineering and research for Raytheon Co.

Latest possible additions to Aerospace's responsibilities are three proposed new missile programs: an advanced – but smaller – version of the Minuteman, a solid fueled IRBM, and an antimissile missile system.

Allis-Chalmers Buys Half of CSC; Industrial Sales is Aim

MILWAUKEE—

Two highly regarded companies who have had a rough time trying to crack the industrial control systems sales nut have joined forces in an unusual control builder-machinery builder tieup. Allis-Chalmers Mfg. Co., Milwaukee-based old line heavy industrial equipment builder, has purchased a one-half interest in Consolidated Systems Corp., a wholly owned subsidiary of Consolidated Electrodynamics Corp.

Allis-Chalmers, which has felt a demand for controls to go with its line of heavy goods, has not been able to indentify itself fully with sophisticated control systems engineering. CEC (itself a subsidiary of Bell & Howell, Chicago manufacturer of movie cameras and office machines) has, on the other hand, had good success with CSC's ventures into systems engineering—but only with the military. CSC has had only token success selling its control systems to industry.

A-C has agreed to purchase 50 percent of CSC's stock in a deal set for quick consummation. Financial details were not disclosed.

CSC is one of the seven operating units of CEC. Formed in 1954, it was incorporated in March 1959 and has been a major customer for instrumentation made by the parent units. CSC has 525 employees, one-third of whom are technical personnel.

Last year the Monrovia, Calif., group undertook or completed 101 systems for a wide range of applications—most of them military. A major job was an automatic data recording, monitoring, and computing system for jet engine testing. The company is also heavily involved in work on the Atlas ICBM.

The joint venture will allow CSC to draw from the hardware reserves

←CIRCLE 44 ON READER SERVICE CARD

of both CEC and Allis-Chalmers. CSC has its own production facilities but no line of proprietary products.

Noting the tremendous increase in recent years of the application of electronic instrumentation to industrial processes, including power generation (one of A-C's strong fields), R. S. Stevenson, president of Allis-Chalmers, said, "Many of our customers are now looking for us to provide them not only with the required major industrial equipment but also the systems control necessary to automate the process."

W. M. Wallace, general manager of A-C's Industrial Equipment Div., pointed out that steel mills and power plants are currently in the process of being automated in various forms, while nuclear power plants, the cement industry, and the pulp and paper field hold great potential for automatic control in the future.

—Stewart W. Ramsey
McGraw-Hill News

British Gyro Maker Denationalized

LONDON—

Disenchanted with nationalization of industry, Britain continues to free state-controlled industries. Last month, S. G. Brown Ltd., producer of gyroscopes and other navigational equipment was sold back to private interests for a sum estimated over $2.8 million after being state controlled since 1942. The new owner: De Havilland Holdings Ltd., which is a member of the Hawker Siddeley Group and which has associated with the U.S.'s American Bosch Arma Corp. in this venture.

But the association with Arma has raised a storm of protest. The British Labor Party, England's staunch advocates of nationalization of industry, and trade unions have denounced the sale as a sellout to American interests, despite safeguards written into the DeHavilland-Arma agreement guaranteeing continued British control.

Arma has had a relationship with the Brown company since 1957 when the British firm took out a license to sell and manufacture Arma designed gyros for military use outside the U.S. and for worldwide commercial applications. The new pact is expected to extend S. G. Brown's interests into new fields which Arma has already surveyed.

News of Other Companies In the Control Field

C-E-I-R, Inc., Arlington, Va., will purchase all the outstanding stock of

(*Continued on page* 190)

CIRCLE 45 ON READER SERVICE CARD→



It's literally a snap with CEC's 5-119V Recording Oscillograph, the first *universal* oscillograph made. Available in 36- and 50-trace models with high-actinic light source, this single recorder accommodates practically every known oscillographic process... without modifications or special tools.

Just snap on the accessory magazine to suit your recording needs of the moment. For example...

TYPE 5-051 SLOT-EXIT MAGAZINE delivers continuous print-out records. And you can use this same magazine for conventional records by closing off the slot exit and adding an internal take-up spool.

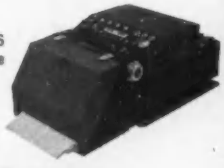
TYPE 5-036 DATARITE MAGAZINE quickly converts the 5-119V to an automatic processing, rapid-access oscillograph . . . provides ready-to-read, permanent records in just 0.8 second after exposure at 25 ips.

DATAFLASH COVER replaces the cover on the DATARITE Magazine and changes it to a *high-speed* print-out magazine that produces records 60 times faster than conventional print-out methods. This is CEC's exclusive DATAFLASH* process.

For more details, call your nearest CEC sales and service office, or write today for Bulletin CEC 1536-X17.

* Patent Pending


5-051
Slot-Exit Magazine

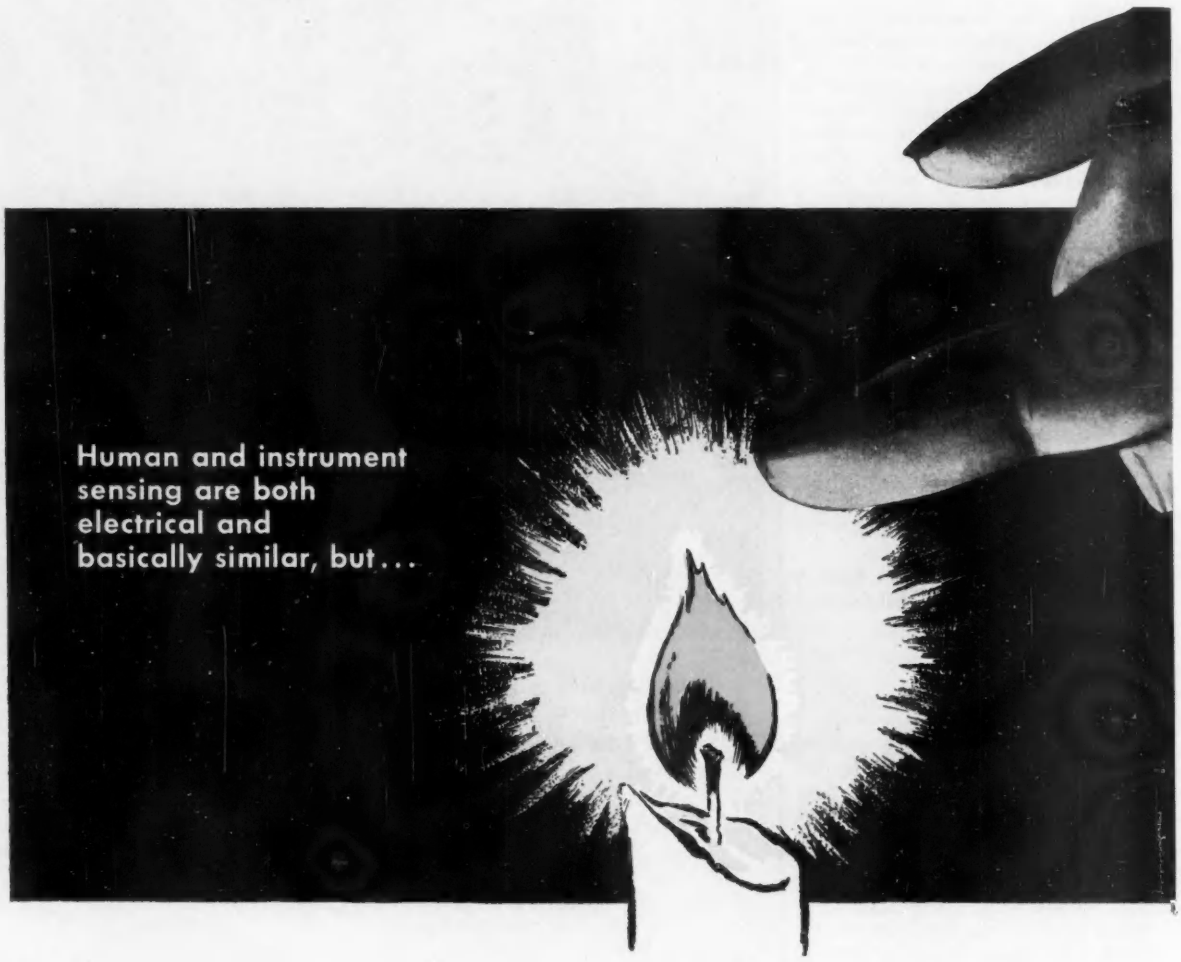
5-036
DATARITE Magazine



DATAFLASH cover
on 5-036 Magazine

Electro Mechanical Instrument Division CEC

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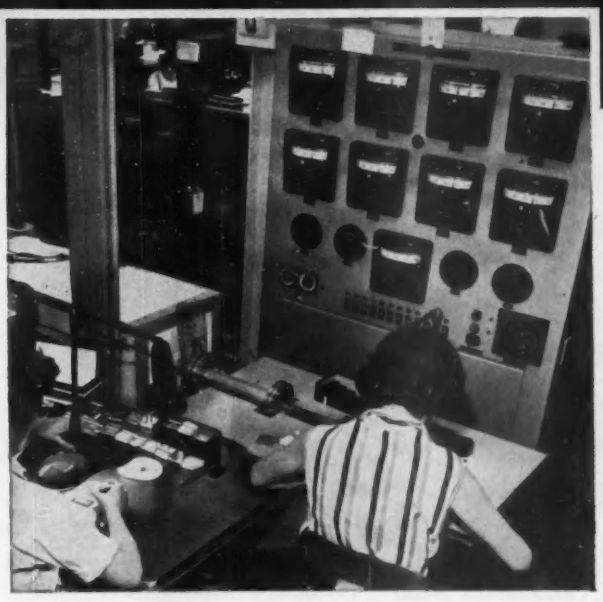
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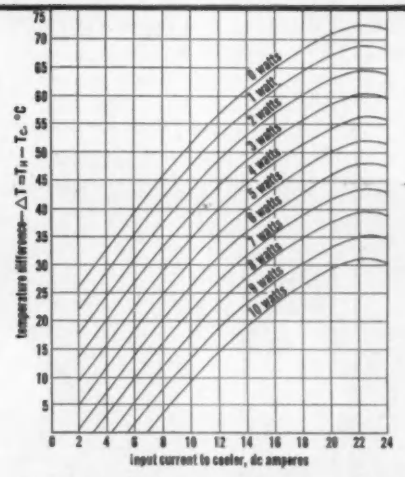
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- You can add intermediate stations without adding any additional transmission lines.

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- Can be used as part of a multiplexing system.

The *Dur-O-Pulse* system measures and transmits process variables such as pressure, temperature, flow, level, voltage, current, power and speed. It can send data quickly and accurately over all types of circuits.



set index setting simplify operation Dur-O-Pulse telemetering systems

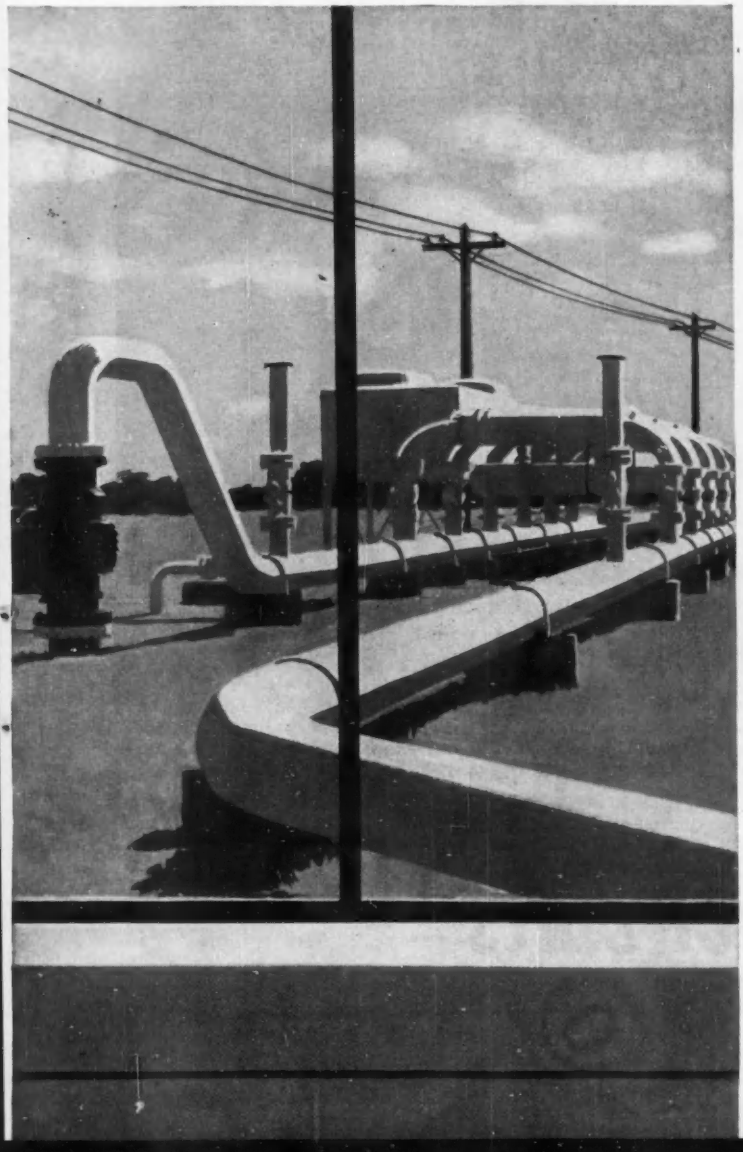
- Gives you set point indication at transmitting and receiving instruments.
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CIRCLE 51 ON READER SERVICE CARD



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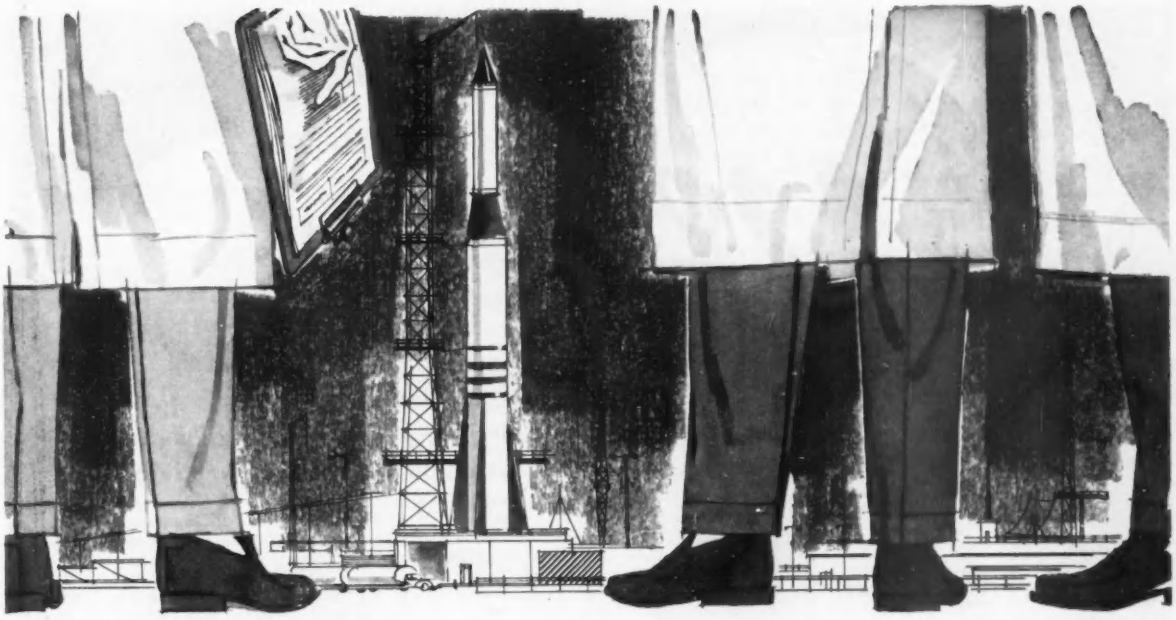
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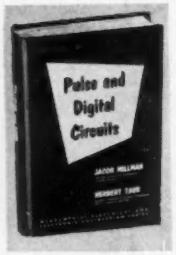
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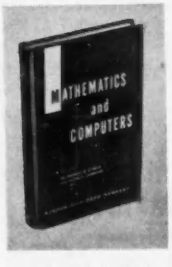
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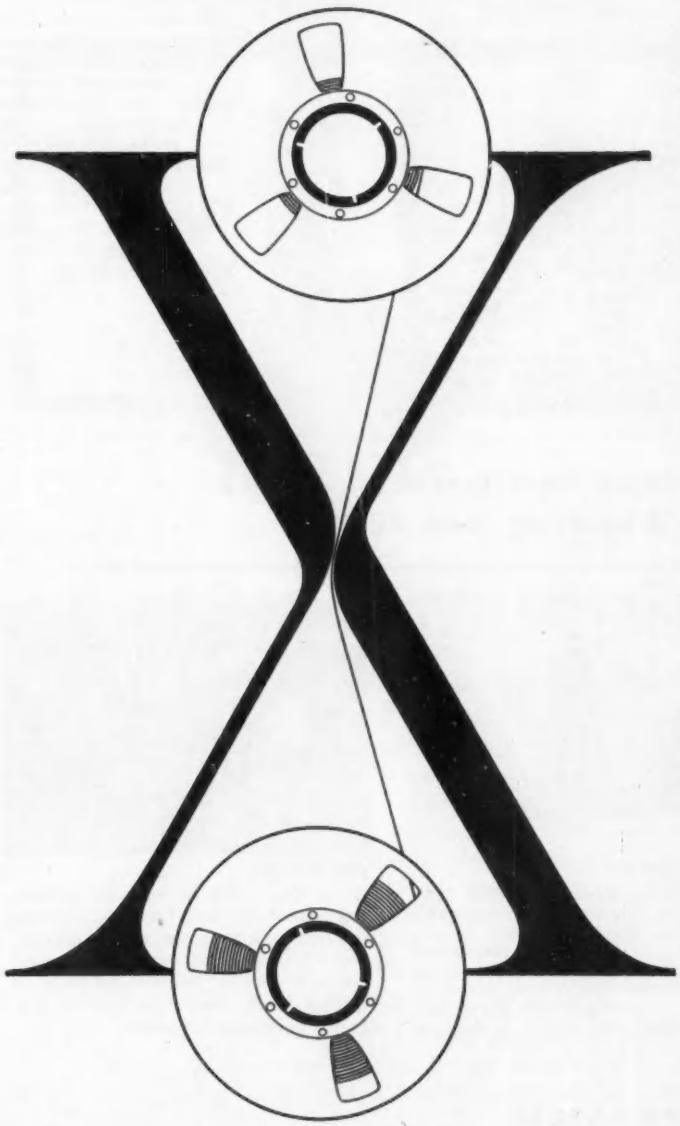
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IN THAT NARROW LITTLE LIFELINE OF DATA known as magnetic tape, a miss is magnified into a mile. A missed bit, or one picked up by error is confusing, frustrating and time-consuming. If you're in doubt about the kind of performance you're getting, perhaps "SCOTCH" BRAND Sandwich Tapes can solve some of your tape and equipment problems.

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The Sandwich is constructed as shown in the diagram at the right. The famous "SCOTCH" BRAND high potency oxide coating is sandwiched between a tough polyester base and a 50 micro-inch layer of plastic. Since the oxide is never in contact with the head, tape movement is smooth and low in friction—easy on both tape and equipment. Oxide can't rub off and distort valuable data.

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FOR INSTRUMENTATION

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...WHERE RESEARCH IS THE KEY TO TOMORROW

STOCK SHIPMENT PROGRAM

26 VOLT FIXED WINDING AND GENERATOR OUTPUT

FRAME SIZE	MOTOR OR MOTOR GENERATOR	FREQUENCY CYCLES	POLES	CONTROL WINDING	PART NUMBER: PLAIN SHAFT ½" x .1200"	PART NUMBER: HOBBED SHAFT 13T x 120P
8	M	400	6	26S	8M61A	8M61B
8	M	400	6	33CT	8M62A	8M62B
8	MG	400	6	26S	8MG61A	8MG61B
8	MG	400	6	33CT	8MG62A	8MG62B
9	M	400	4	26P	9M40A	9M40B
9	M	400	4	26S	9M41A	9M41B
9	M	400	4	26S	9M61A	9M61B
9	M	400	4	26S	9MG41A	9MG41B
9	MG	400	4	26S	9MG61A	9MG61B
9	MG	400	6	26S		

115 VOLT FIXED WINDING AND GENERATOR OUTPUT

					PLAIN SHAFT ½" x .1200"	HOBBED SHAFT 13T x 120P
11	M	60	2	115CT	11M25A	11M25B
11	M	60	2	115P	11M24A	11M24B
11	M	400	6	115S	11M66A	11M66B
11	M	400	6	36CT	11M63A	11M63B
11	MG	400	6	115S	11MG66A	11MG66B
11	MG	400	6	36CT	11MG63A	11MG63B
					PLAIN SHAFT ⅝" x .1870"	HOBBED SHAFT 15T x 96P
15	M	60	2	230S	15M27C	15M27D
15	M	400	4	115S	15M46C	15M46D
15	M	400	4	36CT	15M43C	15M43D
15	M	400	8	115S	15M86C	15M86D
15	M	400	8	36CT	15M83C	15M83D
15	MG	60	2	230S	15MG27C	15MG27D
15	MG	400	4	115S	15MG46C	15MG46D
15	MG	400	4	36CT	15MG43C	15MG43D
15	MG	400	8	115S	15MG86C	15MG86D
15	MG	400	8	36CT	15MG83C	15MG83D
15	M	60	2	280S	18M28C	18M28D
18	M	400	4	115S	18M46C	18M46D
18	M	400	4	36CT	18M43C	18M43D
18	M	400	8	115S	18M86C	18M86D
18	M	400	8	36CT	18M83C	18M83D
18	MG	60	2	280S	18MG28C	18MG28D
18	MG	400	4	115S	18MG46C	18MG46D
18	MG	400	4	36CT	18MG43C	18MG43D
18	MG	400	8	115S	18MG86C	18MG86D
18	MG	400	8	36CT	18MG83C	18MG83D

Key to Symbols—P: Straight Winding (2 leads) S: Split Winding (4 leads) CT: Center Tapped Winding (3 leads)

SPECIFICATIONS:

ROTORS—	8 through 11	15 through 18
shaft extension	½ inch	⅝ inch
plain shaft O.D.	0.120 inch	0.1870 inch
hobbed shaft teeth	13 T	15 T
hobbed shaft pitch	120 P	96 P

BEARINGS — EB lubrication; LEADS — 8" minimum; DELIVERY — shipped five working days from receipt of order; QUANTITY — presently limited to five units, subject to change. Part numbers do not appear on decals.

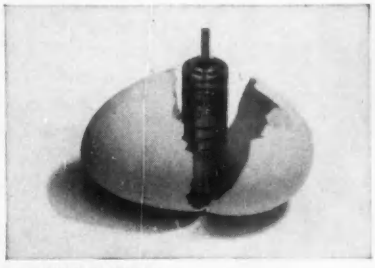
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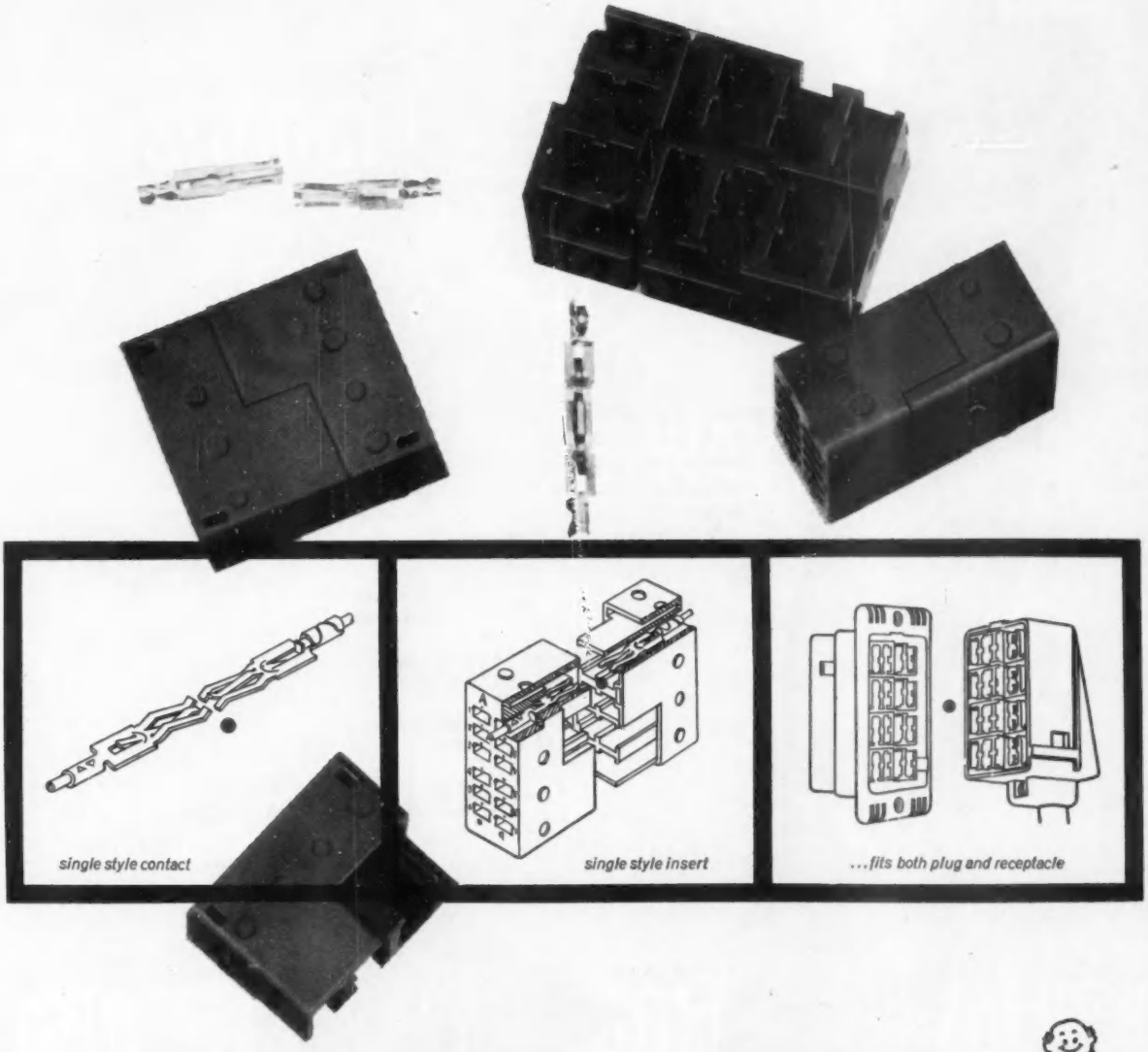
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* tradename pat pend

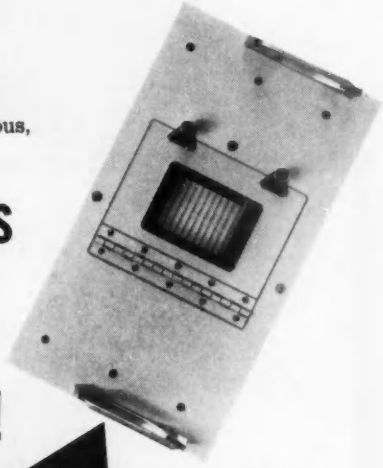
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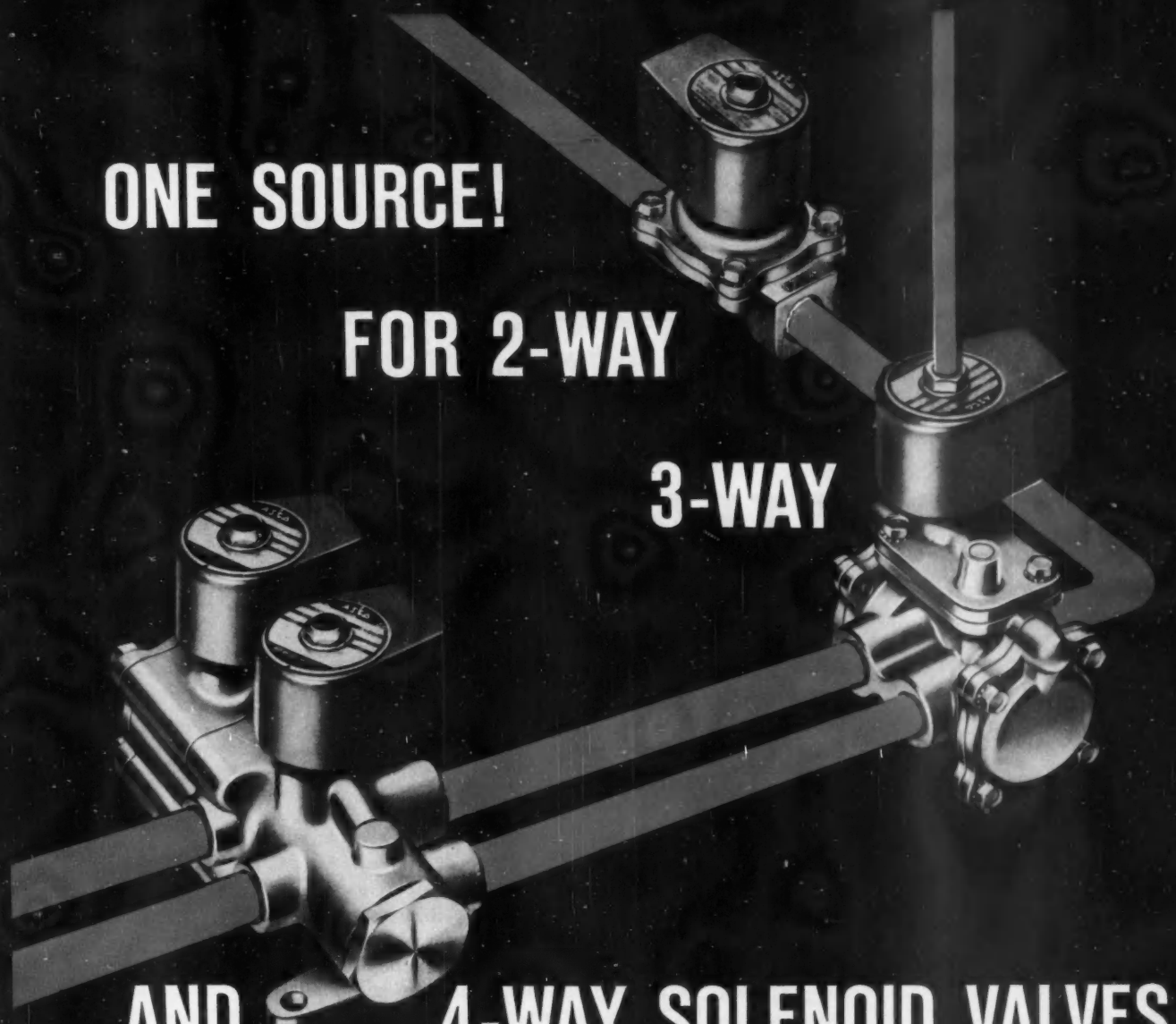
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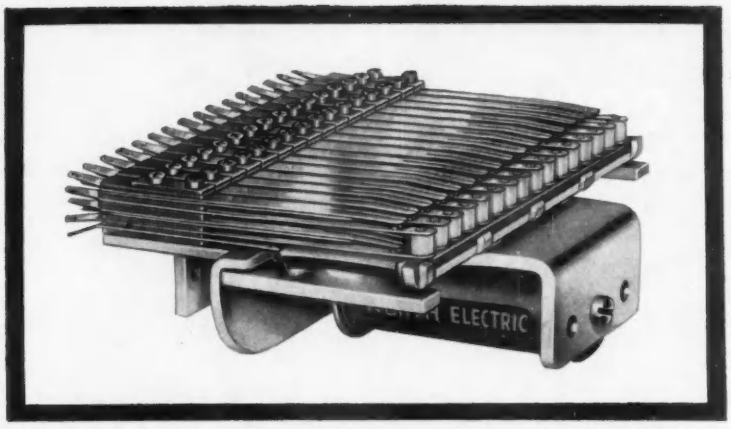
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Where reliability is a must—North 700 Series "gang" relays combine fast action multiple circuit switching capabilities with the proven dependability of a telephone type open relay for use in computers, sorting and punching machines and similar applications. North 700 Series relays provide up to 16 pile-ups and are available to 32 form A or to 16 form B or form C contact arrangements.

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For applications where the small number of relays in a switching system make a common DC power supply uneconomical, the North 7300 Series is available with AC rectifiers.

North "gang" relays can be supplied with Double Gold Alloy or Solid Silver contacts, with solder type or AMP #78 type contact terminals, and with 12, 24, 48, 75 and 110 volt coils (110 V.A.C. for 7300 Series). Operating speeds range from 30 MS to 70 MS at approximately 2.2 watts. Faster speeds can be obtained with increased power.

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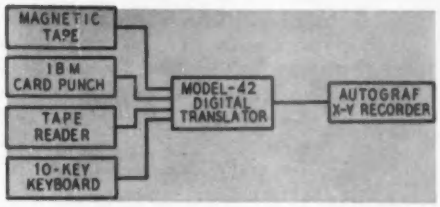


Moseley Model 42 Digital Translator allows automatic operation of Autograf or similar X-Y Recorders from digital data supplied by any conventional source. Accuracy of digital-to-analog conversion is 0.1% and the accuracy of Moseley AUTOGRAF recorders, 0.15%, is maintained.

Model 42 is compatible with IBM Summary Punches and Card Readers including Models 514, 519, 523, 524, 526, etc. It may also be driven, without modification to either the Translator or driving equipment, by mechanical punched tape readers such as Friden, Soroban solenoid and Teletype motorized readers.

Model 42 is supplied with a 10-key serial keyboard for manual input. Accessories include magnetic tape adapter, Flexowriter converter, remote decimal contents read-out panel and optical magnetic tape converter. Model 42, including keyboard, $4,500.00.

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CIRCLE 61 ON READER SERVICE CARD

INERTIAL COMPONENTS

SUB-SYSTEMS AND FLIGHT TEST EQUIPMENT

RATE GYROSCOPES



TYPE M-100 is the latest in Honeywell's family of miniaturized high performance rate gyros. It features constant damping (0.6 at −65°F) over a wide operating temperature range without the use of heaters.



TYPE GN or "Golden Gnat" is another of Honeywell's high performance gyros and has been in full production in a wide variety of miniature rate packages over the past three years.

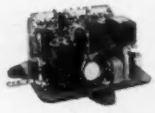


TYPE JR, another rate gyro of proven reliability, features a unique quadrilever spring suspension for high sensitivity and a wide full range under severe environmental conditions; TYPE JRT is available with heaters for those critical applications requiring constant damping; TYPE K Rate Measuring Gyro features a linear output signal that is proportional to the input rate within 0.25% full scale.

INERTIAL SUB-SYSTEMS

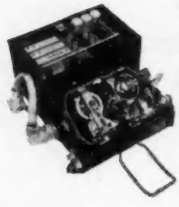


F-102 THREE-AXIS RATE GYRO SYSTEM Instantaneous detection of aircraft turning rates about the roll, pitch, and yaw axes is accomplished by three Model JR gyros. The resulting output signals teamed with other equipment, make possible uniform pilot control response for all flight conditions.



F-106 THREE-AXIS TURN RATE TRANSMITTER This sub-system features three Gnat miniaturized gyros that detect rate of turn about the roll, pitch, and yaw axes and responds with an output signal to provide polarity reversing D-C outputs proportional to the corresponding input rate.

CONTRACT ENGINEERING AND MANUFACTURING



Honeywell's Boston Division will design from customer specifications or prototypes, or manufacture to customer's drawings. Typical of the completed programs in this area are: CN-100 Compass-controlled Stable Reference Platform for a bombing system (shown at left), and Displacement Gyros for the A1A/BNC Bombing Navigational Computer.

ACCELEROMETERS



TYPES LA-100, LA-300 are low cost, rugged, linear, non-pendulous units with potentiometer outputs.



TYPE LA-200 is a miniaturized, pendulous, linear accelerometer which is fluid-damped and mechanically compensated. Output signal is provided by a variable reluctance signal generator.



TYPE LA-500 is a linear, non-pendulous, fluid-damped potentiometer output device that features constant damping, linear response, (−65° and +175°F).

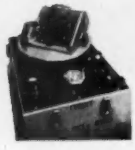


TYPE LA-600 is a linear, non-pendulous A-C accelerometer in which pick-off friction is eliminated to permit resolution of extremely low level inputs. This accelerometer features magnetic damping for near constant damping ratio (−65°F to +250°F).



TYPE LA-700 linear, non-pendulous accelerometer is a complementary unit to the LA-600 for those applications requiring a high full-scale range combined with a low natural frequency.

TEST EQUIPMENT



HONEYWELL RATE GYRO TEST SET designed for use by field personnel for the static analysis of rate gyros, rate gyro demodulator amplifier, and three-axis rate gyros packages. This equipment meets the design requirements of MIL-T-945 and environmental test requirements outlined in MIL-E-4970.

SPECIALIZED TEST EQUIPMENT such as Radar Range Servo Test Sets, Frequency Response Analyzers, and other electronic equipment can be designed and manufactured to meet your requirements.

FLIGHT TEST EQUIPMENT



TYPE DV-4 POWER SUPPLY-DEMODULATOR (115 volt, 400 cycle, single-phase primary power available) energizes 1 to 3 Honeywell Rate Measuring Gyros, Type K, and translates the gyro output signals to a form suitable for use with recording oscillograph galvanometers or tape recorders.

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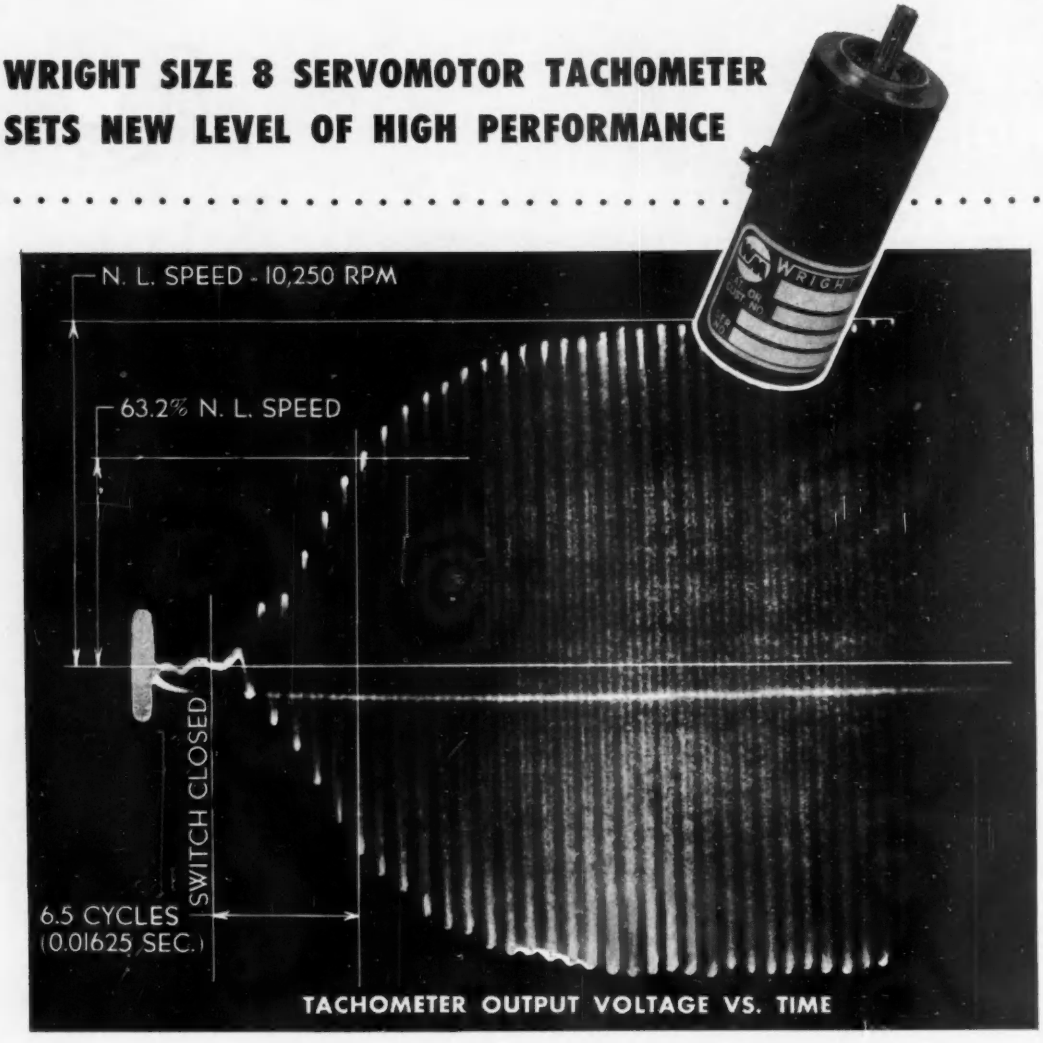
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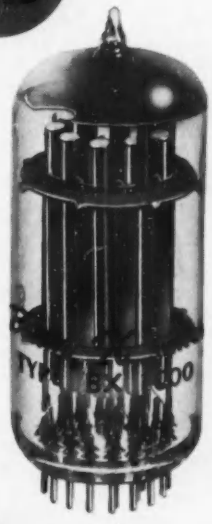
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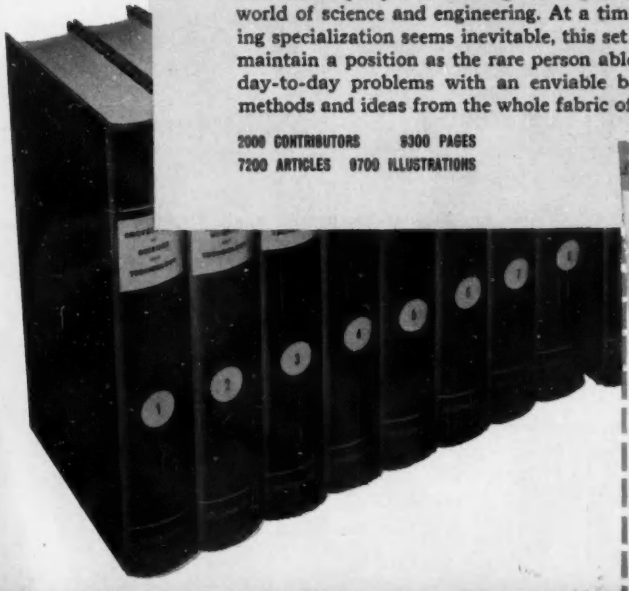
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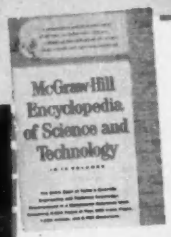
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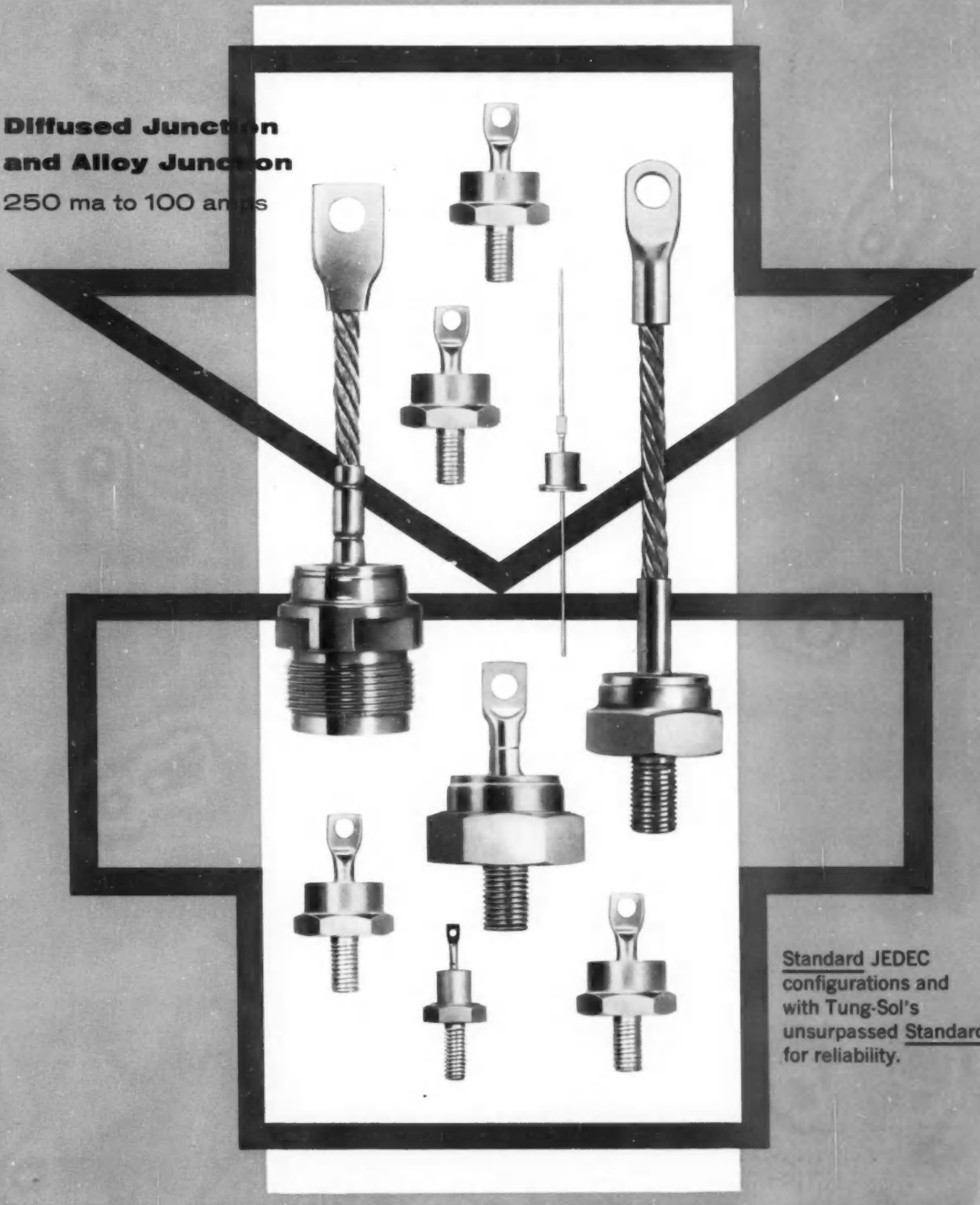
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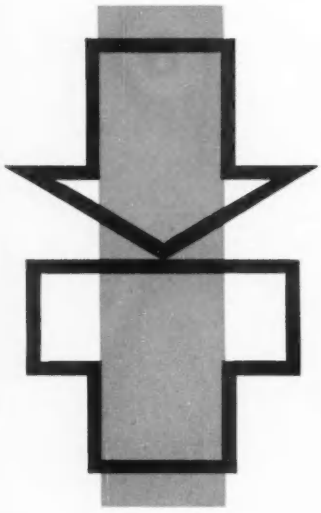
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SILICON POWER RECTIFIERS

Diffused Junction
and Alloy Junction
250 ma to 100 amps



Standard JEDEC configurations and with Tung-Sol's unsurpassed Standard for reliability.



TUNG-SOL®

SILICON POWER RECTIFIERS

This select line fits the broadest variety of applications. Each unit delivers across-the-board versatility and directly replaces many existing types.

- They are designed to serve with unqualified dependability in the most exacting military and commercial applications.
- They are manufactured to exceed the most stringent conditions imposed by military specifications.
- They are conservatively rated to assure unexcelled long-term reliability.
- They feature very low forward voltage drop and low reverse leakage ratings which promote high rectification efficiency, excellent regulation and very low internal losses.
- They are precision engineered to assure the utmost in top-performance uniformity and stability, and to function at maximum capacity even under the most severe environmental and electrical overload conditions.
- They carry with them the built-in reliability and peak performance standards associated with all Tung-Sol components—a result of Tung-Sol's pace-setting quality assurance program.

AUGUST 1960



	Type	Peak Reverse Voltage (Volts)	Average Forward Current	Maximum Reverse Current *	Max. Full Load Voltage Drop (Volts)	Surge Current† (Amps)
250- mA 150°C Ambient Temperature	1N538	200	750 mAdc @ 50°C 250 mAdc @ 150°C	250 μAdc	0.5	
	1N540	400	750 mAdc @ 50°C 250 mAdc @ 150°C	250 μAdc	0.5	
	1N547	600	750 mAdc @ 50°C 250 mAdc @ 150°C	250 μAdc	0.5	
1 Amp 150°C Case Temperature	1N253	100	1.0 Adc	100 μAdc	—	
	1N254	200	0.4 Adc	100 μAdc	—	
	1N255	400	0.4 Adc	150 μAdc	1.0 ▲	
	1N256	600	0.2 Adc	250 μAdc	—	
20 Amp 140°C Case Temperature	1N1191	50	20 Adc	5 mAdc	.55	250
	1N1192	100	20 Adc	5 mAdc	.55 Full	250
	1N1193	150	20 Adc	5 mAdc	.55 cycle	250
	1N1194	200	20 Adc	5 mAdc	.55 avg.	250
	1N1195	300	20 Adc	5 mAdc	.55 @	250
	1N1196	400	20 Adc	5 mAdc	.55 150°C	250
	1N1197	500	20 Adc	5 mAdc	.55 case	250
	1N1198	600	20 Adc	5 mAdc	.55 temp.	250
25 Amp 150°C Case Temperature	CS-120Z	50	25 Adc	5 mAdc	.55 Full	350
	CS-120A	100	25 Adc	5 mAdc	.55 cycle	350
	CS-120B	200	25 Adc	5 mAdc	.55 avg.	350
	CS-120C	300	25 Adc	5 mAdc	.55 @	350
	CS-120D	400	25 Adc	5 mAdc	.55 150°C	350
	CS-120E	500	25 Adc	5 mAdc	.55 case	350
	CS-120F	600	25 Adc	5 mAdc	.55 temp.	350
35 Amp 140°C Case Temperature	1N1183	50	35 Adc	10 mAdc	0.6	500
	1N1184	100	35 Adc	10 mAdc	0.6 full	500
	1N1185	150	35 Adc	10 mAdc	0.6 cycle	500
	1N1186	200	35 Adc	10 mAdc	0.6 avg.	500
	1N1187	300	35 Adc	10 mAdc	0.6 @	500
	1N1188	400	35 Adc	10 mAdc	0.6 140°C	500
	1N1189	500	35 Adc	10 mAdc	0.6 case	500
	1N1190	600	35 Adc	10 mAdc	0.6 temp.	500

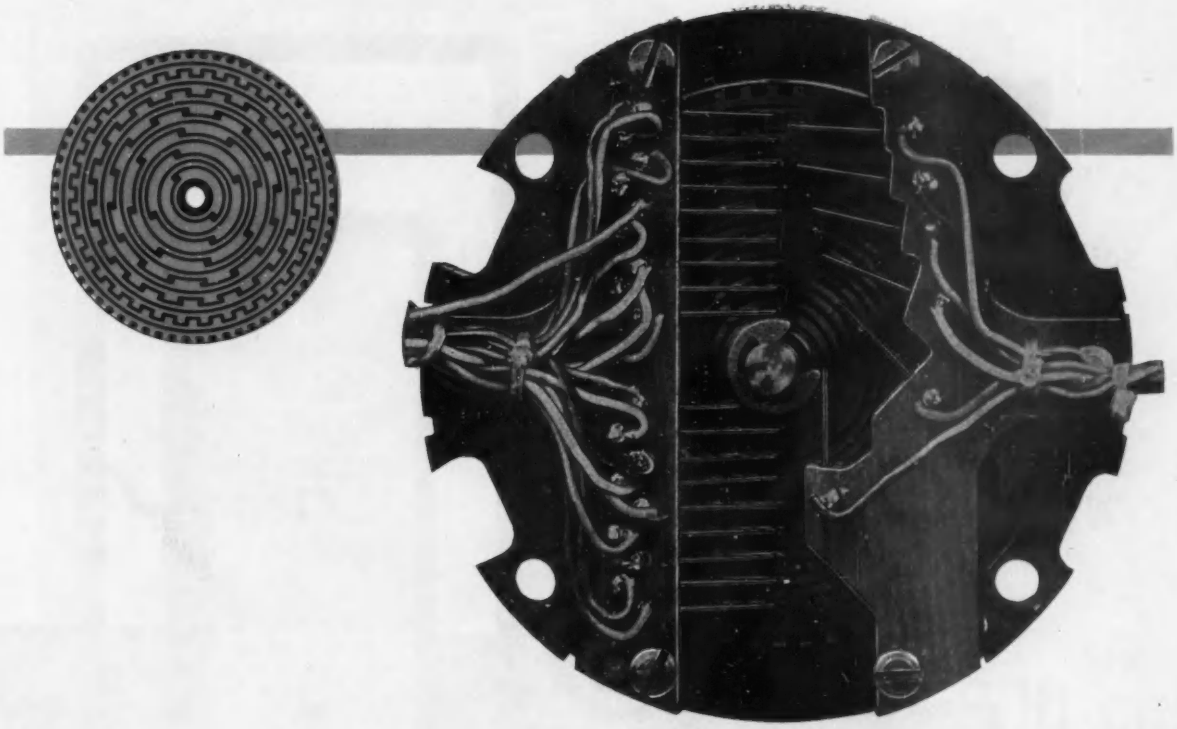


	Type	Peak Reverse Voltage (Volts)	Average Forward Current	Maximum Reverse Current*	Fwd. Voltage Drop** (Volts)	Surge Current† (Amps)
50 Amp 150°C Case Temperature	CH116Z	50	50 Adc	20 mAdc	1.1	500
	CH116A	100	50 Adc	20 mAdc	1.1	500
	CH116B	200	50 Adc	20 mAdc	1.1	500
	CH116D	400	50 Adc	20 mAdc	1.1	500
	CH116F	600	50 Adc	20 mAdc	1.1	500
70 Amp 150°C Case Temperature	1N1396	50	70 Adc	15 mAdc	1.3	1500
	1N1397	100	70 Adc	15 mAdc	1.3	1500
	1N1398	150	70 Adc	15 mAdc	1.3	1500
	1N1399	200	70 Adc	15 mAdc	1.3	1500
	1N1400	300	70 Adc	15 mAdc	1.3	1500
	1N1401	400	70 Adc	15 mAdc	1.3	1500
	1N1402	500	70 Adc	15 mAdc	1.3	1500
70 Amp 150°C Case Temperature	CH109Z	50	70 Adc	30 mAdc	1.3	1500
	CH109A	100	70 Adc	30 mAdc	1.3	1500
	CH109B	200	70 Adc	30 mAdc	1.3	1500
	CH109C	300	70 Adc	30 mAdc	1.3	1500
	CH109D	400	70 Adc	30 mAdc	1.3	1500
	CH109E	500	70 Adc	30 mAdc	1.3	1500
80 Amp 150°C Case Temperature	1N1291	50	80 Adc	30 mAdc	1.3	1500
	1N1292	100	80 Adc	30 mAdc	1.3	1500
	1N1293	200	80 Adc	30 mAdc	1.3	1500
	1N1294	400	80 Adc	30 mAdc	1.3	1500

▲ Max. fwd. voltage drop @ 0.5 amp., 25°C case temperature
* Full cycle average for rectifier operating into inductive or resistive load at rated current and voltage
** 50 amp units @ 100 amps D.C. and 25°C;
70 and 80 amp units @ 150 amps D.C. and 25°C
† Max. half sine wave peak current for one cycle @ 60 cps
Storage temperature range for all types . . . -65° to 200°C

Write for the new Tung-Sol interchangeability chart and complete technical information. Tung-Sol Electric Inc., Newark 4, N. J. Technical assistance is available through the following sales offices: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Texas; Denver, Colo.; Detroit, Mich.; Irvington, N. J.; Melrose Park, Ill.; Newark, N. J.; Philadelphia, Pa.; Seattle, Wash. Canada: Toronto, Ont.

TUNG-SOL®



Norden converters eliminate external electronics, simplify circuitry by non-ambiguous, self-selecting brush design

Unique Norden self-selecting V-scan pattern translates analog input into digital electrical representation by means of self-contained, non-ambiguous, dual brush-selection logic. This Norden design

- offers the *only* shaft position encoders to qualify under MIL-E-5422D and MIL-E-5272A.
- simplifies total system design and reduces cost.
- has provision for automatic error-monitoring.
- has precision brushes, fewer components and unambiguous output assuring highest reliability.
- saves space . . . ideal for subminiature techniques.
- permits direct parallel readout accurately following the shaft position even at highest shaft speeds.
- has longer life because no load current-carrying brush ever commutates; insulation of only 19% of disc area minimizes brush wear and insulation dust.

MODEL NO.	TOTAL COUNT	REVOLUTIONS PER COUNT	(1 PART IN) ACCURACY
ADC-ST7-BNRY	2^7	1	128
ADC-13-BNRY	2^{13}	64	8192
ADC-19-BNRY	2^{19}	4,096	524,288
ADC-ST8P-BNRY	2^8 (with parity)	1	256
ADC-ST9-BNRY	2^9	1	512
ADC-ST10-BNRY	2^{10}	1	1024

These Norden self-selecting V-Brush encoders fit a wide variety of applications. For complete specifications and drawings, call Milford, Connecticut, TRinity 4-6721. If your requirements demand special variations, Norden engineers will work out a custom design.

NORDEN

NORDEN DIVISION
UNITED AIRCRAFT CORPORATION
MILFORD DEPARTMENT, WILEY STREET, MILFORD, CONNECTICUT

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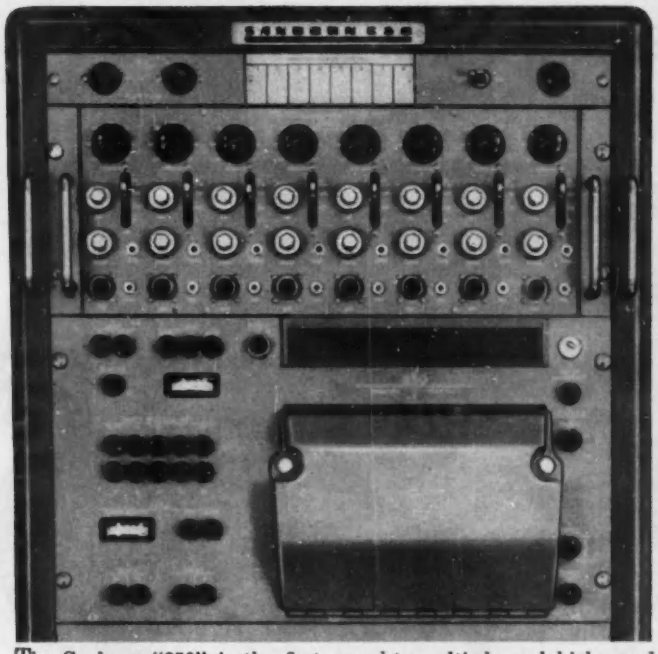
Qualified engineers seeking rewarding opportunities in these advanced fields are invited to get in touch with us.

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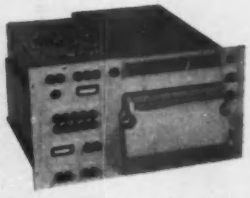
8RV60





8-channel Amplifier

+



2000 cps Optical Recorder

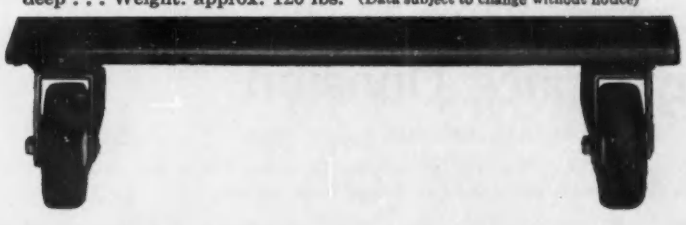
= a new 0 to 5000 cps direct writing system

SANBORN "650" SERIES

The Sanborn "650" is the first *complete* multi-channel high-speed optical recording system with medium gain general purpose amplification for each channel. Either the 8-channel amplifier or the recorder may be used separately. Together they provide a max. sensitivity of *2.5 mv/in* and a frequency response of *DC to 5000 cps* (within 3 db at 4 in peak-to-peak) in a multi-channel "direct writing" system.

MODEL 658-3400 GENERAL PURPOSE AMPLIFIER. Here is the first sensitive multi-channel amplifier designed specifically for use with high frequency optical galvanometers — those in the Sanborn "650" and any similar recorder. The single chassis has 8 separate channels, each one complete from floating and guarded signal input to galvanometer output. They include front-end modulator and input transformer, medium gain carrier amplifier, demodulator, filter and driver amplifier. An internal pre-emphasis circuit increases galvanometer frequency range from 2000 cps to 5000 cps in the "650" recorder. The all transistorized circuitry is mounted on easily serviced printed plug-in cards. The Amplifier chassis has an output transfer chassis on the rear which simplifies coupling to optical recorders of other manufacturers. External damping resistors are easily added when required.
Specifications: Sensitivity: 7.2 ma/mv input, max. . . . Attenuation: X2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000 . . . Common Mode Performance: tolerance — 500 volts max; rejection — 140 db for DC . . . Input Resistance: 100,000 ohms all ranges floating and guarded.

MODEL 650 1- TO 24-CHANNEL OPTICAL RECORDER. The Model 650 Recorder provides high frequency direct writing recording, flexible housing and wide application possibilities. It may be used separately with from 1 to 24 plug-in type galvanometers of various natural frequencies. When used *with the 658-3400 Amplifier*, the recorder is equipped with eight 2000 cps galvanometers — extended to 5000 cps by the amplifier pre-emphasis circuit — for wide range, high speed, wide deflection recording. The recorder has nine electrically controlled (local or remote) chart speeds, beam interrupters for trace identification, timing lines at 0.01 or 0.1 sec intervals; amplitude lines with manual washout from ¼, ½, ¾ or all of the record; full chart width deflection for each trace and trace overlap.
Specifications: Input Sensitivity: 17.5 ma/inch (with 2000 cps galvanometers) . . . Chart Speeds: 0.25, 0.5, 1.0, 2.5, 5.0, 10, 25, 50 and 100 inches/second . . . Dimensions: 19" wide by 17½" by 16½" deep . . . Weight: approx. 120 lbs. (Data subject to change without notice)



Complete data is available from Sanborn Sales-Engineering Representatives located in principal cities throughout the United States, Canada and foreign countries.

SANBORN COMPANY

INDUSTRIAL DIVISION
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These ground service carts supply clean, high-pressure air for any airport use—could even power a jet engine starting system! They also can pressurize missile pneumatic systems, shock isolation and air suspension systems, or ground support equipment. Can even run air tools. They are an ideal source of high-pressure air for in-plant use, too.

Some particulars: 4 cfm compressor (illustrated) 5,000 psi; 900 cubic inch wire wound steel air reservoir; moisture separator and chemical drier; outlet pressure regulator; with electric drive (gasoline drive available). Approximate weight 150 pounds. For more information, write Kidde today.

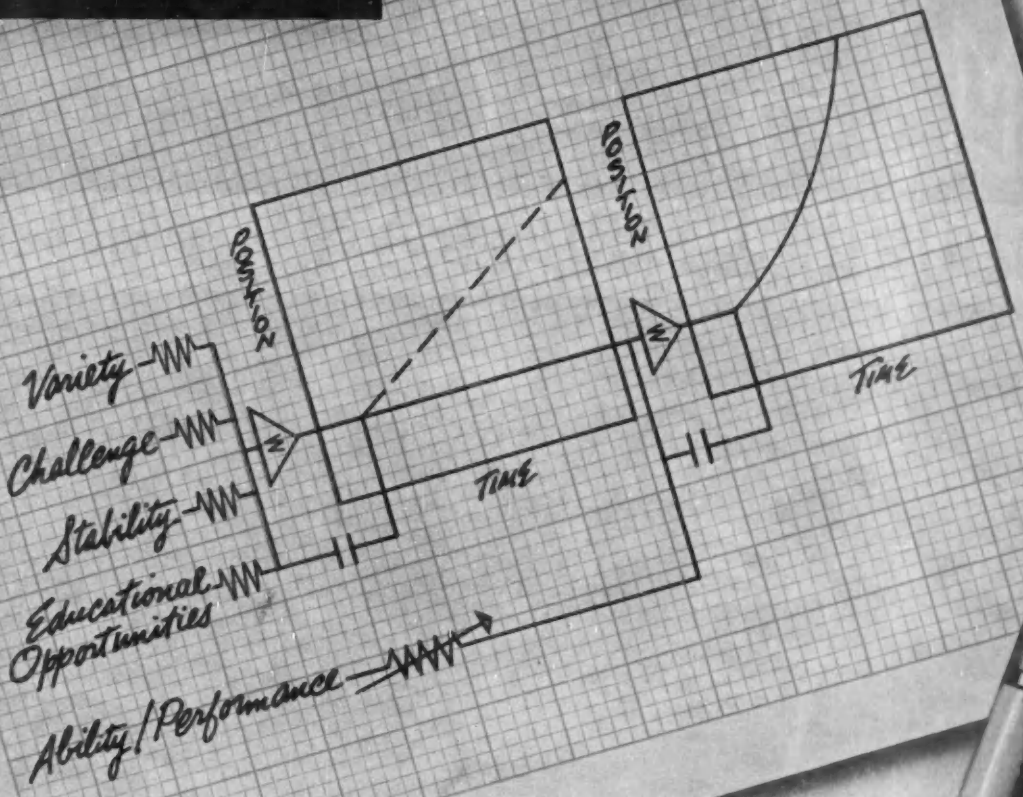
Kidde Aero-Space Division

Walter Kidde & Company, Inc., 817 Main St., Belleville 9, New Jersey

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Engineers / Scientists

FROM AN ENGINEER'S NOTE PAD



"You plot your own curve at HMED"

ENGINEERS ARE a curious lot; a breed apart. Their natural preferences for facts, their talents for logic have been trained and disciplined.

The result many times...an uncommon, refreshing way of expressing the well known...a direct, succinct method of stating the complex.

Here is an actual example. It is a composite of sketches made by one of our Engineering Supervisors during a discussion of General Electric's unique Salary Administration Program.

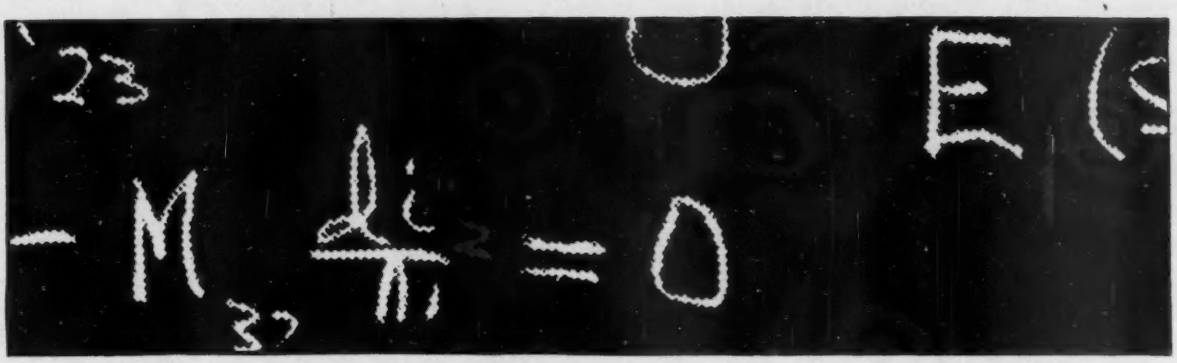
Circuit engineers will have little trouble in reading it. Others may have more difficulty. All may wish additional detail. For this, as well as other information regarding the unusual professional and outstanding personal opportunities awaiting you at General Electric's Heavy Military Electronics Department, write in confidence to George B. Callender.

HEAVY MILITARY ELECTRONICS DEPARTMENT

GENERAL ELECTRIC

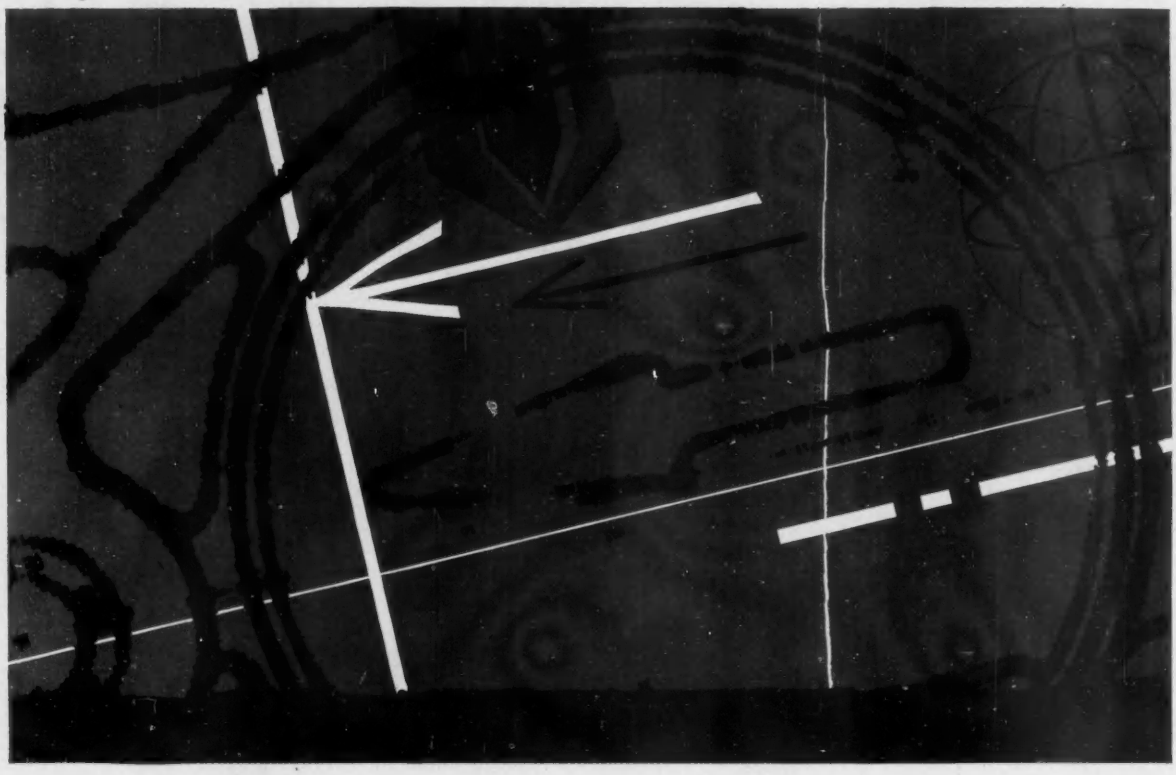
Div. 22 MH Syracuse, New York

There are openings for graduate engineers at intermediate (3 or more years) and high levels of experience in the following areas: **Weapons Systems Analysis; Mathematical Analysis of Engineering Problems; Military Communications Systems; Radar Systems; Weapons Control Systems; Electronic Circuitry; Experimental Psychology—Human Factors; Instrumentation.**



General Motors pledges

AC QUESTMANSHIP



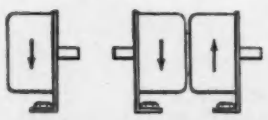
AC Seeks and Solves the Significant—AC Design and Development is moving far ahead in new technology—the result of GM's commitment to make ever larger contributions to the defense establishment. AC plans to resolve problems even more advanced than AChiever inertial guidance for Titan / This is AC QUESTMANSHIP. It's a scientific quest for the development of significant new components and systems . . . to advance AC's many projects in guidance, navigation, control and detection / Dr. James H. Bell, AC's Director of Navigation and Guidance, sees this as a "creative challenge". His group takes new concepts and designs them into producible hardware having performance, reliability and long life. He strongly supports the fact that an AC future offers scientists and engineers "a great opportunity to progress with a successful and aggressive organization" / If you have a B.S., M.S., or Ph.D. in the electronics, scientific, electrical or mechanical fields, plus related experience, you may qualify for our specially selected staff. If you are a "Seeker and Solver", write the Director of Scientific and Professional Employment, Mr. Robert Allen, Oak Creek Plant, 7929 So. Howell Ave., Milwaukee, Wisconsin.

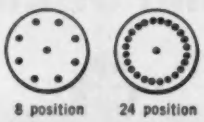
GUIDANCE / NAVIGATION / CONTROL / DETECTION / AC SPARK PLUG *The Electronics Division of General Motors*

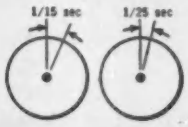


New Ledex Digimotor®

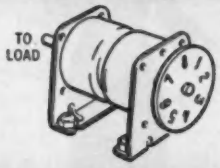
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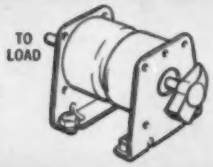


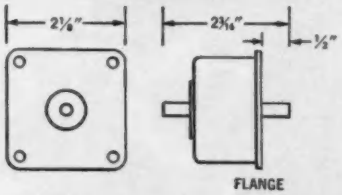


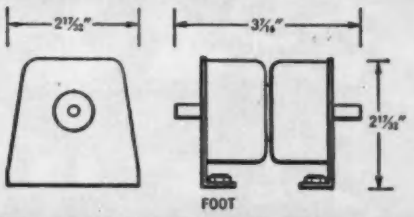


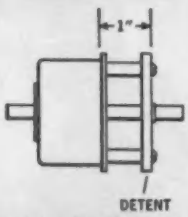












The new Ledex *Digimotor* is a stepping motor or indexing device with exceptionally high reliability and torque-to-size ratio. Its new design concept gives it features never before available. Size 5 stock models come in a variety of shaft positions and in any duty cycle within a wide operating voltage range. It is jam proof, permanently lubricated, has magnetic anti-overcoast, and operates at "whisper" noise level.

New Ledex *Digimotor Switches* are rotary selector switches with all advantages of the Digimotor drive plus other special features.

LEDEX®

Ledex, Inc. was formerly G. H. Leland, Inc.

Other Ledex products include Rotary Solenoid, Rotary Solenoid Selector Switch, Hermetically Sealed Selector Switch, and *Syncramental* Stepping Motor. Mechanical applications include actuation of valves, vanes, printers, shafts. Switching applications include circuit selecting, stepping, counting, programming and sequencing. Write for literature, mentioning application, to Ledex, Inc. (formerly G. H. Leland, Inc.), Dayton 2, Ohio; Marsland Engineering, Ltd., Kitchener, Ont.; NSF Ltd., 31 Alfred Place, London, Eng.; NSF GmbH, Nurnberg, Germany.

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National Education Act Helps Two Ways

At Lower Columbia Junior College (Longview, Wash.) students of industrial instrumentation have a new well-equipped laboratory in which they can study at first hand process control equipment. At Long Beach City College (Long Beach, Calif.) technicians and engineers can take courses in numerical control, putting theory to practice on a numerically controlled continuous contouring index mill. At Philadelphia's Murrell Dobbins Vocational-Technical School, a new instrumentation laboratory will start operating in September. These are just three of the schools that have bought instrument and control equipment with help from the National Defense Education Act of 1958.

Double-edge

Last month the Defense Education Act reached the halfway point in its four-year life. For the measurement and control industry, the act is turning out to have a double-edged benefit: first, it is setting up a supply of well-trained technicians and specialists in control technology, and secondly, purchases of instrumentation and control for the program are adding up to an unexpectedly large market.

One result of the act has been the establishment of industrial education centers around the United States, outfitted with equipment purchased with federal grants that are matched by state and local governments. These centers are becoming fertile training grounds for technicians. In North Carolina, for example, eight industrial education centers have already been completed, 10 more are under construction. In New York State, four centers, to which students can be transported from surrounding high schools, are being expanded and equipped.

Nebraska, on the other hand, has spent most of its money on equipment for one vocational technical high school, located at Milford. The state plans to use the school for post high school training in 10 areas of technology, one of which is instrumentation.

Computer programmers

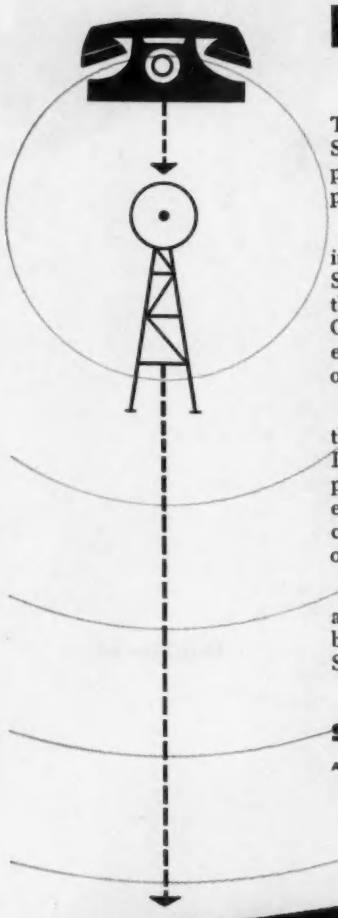
California has been particularly aggressive in pursuing vocational education in the measurement and control field under the terms of the act. For example, 10 junior colleges have set up programs to train students in the use of computers and computer programming. And there will be 15 by next year. The Orange Coast College, to cite one school, has installed over $100,000 worth of data processing and programming equipment.

Numerical control

The numerical control curriculum at Long Beach City College is aimed at tool design students, maintenance technicians, and apprentice machinists. Tool designers will learn the capabilities and limitations of numerically controlled machine tools. Maintenance technicians will concentrate on the electronics of the control system, will be introduced to servosystems and the special circuitry that accompanies numerical control. The apprentice machinists will spend the most time with

PRINTS 3,000 WORDS/MIN

FROM REMOTE POINTS



The U.S. Army Corps of Engineers is using Stromberg-Carlson—San Diego's new S-C 3000 High Speed Communications Printer to print 3000 words a minute from remote sources. The equipment can print out over great distances, using standard wire or radio links.

The S-C 3000 is compatible with most available data link systems, including the Collins Kineplex data transmission system and the Stromberg-Carlson Binary Data Link. Printing is accomplished through a unique combination of the Stromberg-Carlson CHARACTRON® shaped beam tube and Haloid Xerox Inc's., electrostatic printing process. The S-C 3000 prints without impact on untreated paper or lithographic masters.

This new communications printer answers the need for equipment that can keep pace with today's high speed communications systems. It is designed for military, government, news service, business and public communications systems where speed and reliability are essential. The S-C 3000 accepts data via wire or radio link from computers located at a distant point and prints out copy of outstanding readability.

If you are interested in high-speed printing of data received from a distant point, don't fail to investigate the S-C 3000. Write for free booklet to Stromberg-Carlson-San Diego, Dept. A-61, P.O. Box 2449, San Diego 12, California. Telephone BRowning 6-3911

STROMBERG-CARLSON-SAN DIEGO
A DIVISION OF **GENERAL DYNAMICS CORPORATION**



Long Beach's $30,000 Micro-Path controlled index mill. But these will be second year students only, who have already demonstrated proficiency with other conventional advanced machine tools such as tool cutters and precision surface cutters.

$1 billion total

With the passage of the National Education Act, Congress authorized the expenditure of $1 billion, has so far appropriated more than $275 million. The bulk of this has gone for scholarships, teacher training, and teacher salaries primarily in the fields of science and foreign language. One result that has a long run benefit: with this federal money many small high schools have started teaching science courses for the first time. Previously, they had not been large enough to be able to afford such curricula. The increase in basic scientific training is likely to lead to more competent technicians and a bigger supply of engineers.

Local school districts have substantially improved their facilities for teaching science, language, and mathematics. With three-fourths of the expenditures for such facilities going for instrumentation in science course laboratories, the states approved 9,000 local projects in the first year of the program, 18,000 in the second year. In Oklahoma, for example, expenditures per student for science equipment rose from $1.24 to $16.54 during the first year of the program.

$6 million a year

To aid vocational training under Title Eight of the act, an estimated $6 million per year is being spent on measurement and control equipment. The bulk of the funds go to vocational or trade schools (33 percent) and high schools (30 percent). Others receiving aid: technical high schools and institutes, community or junior colleges, and four-year colleges with vocational programs.

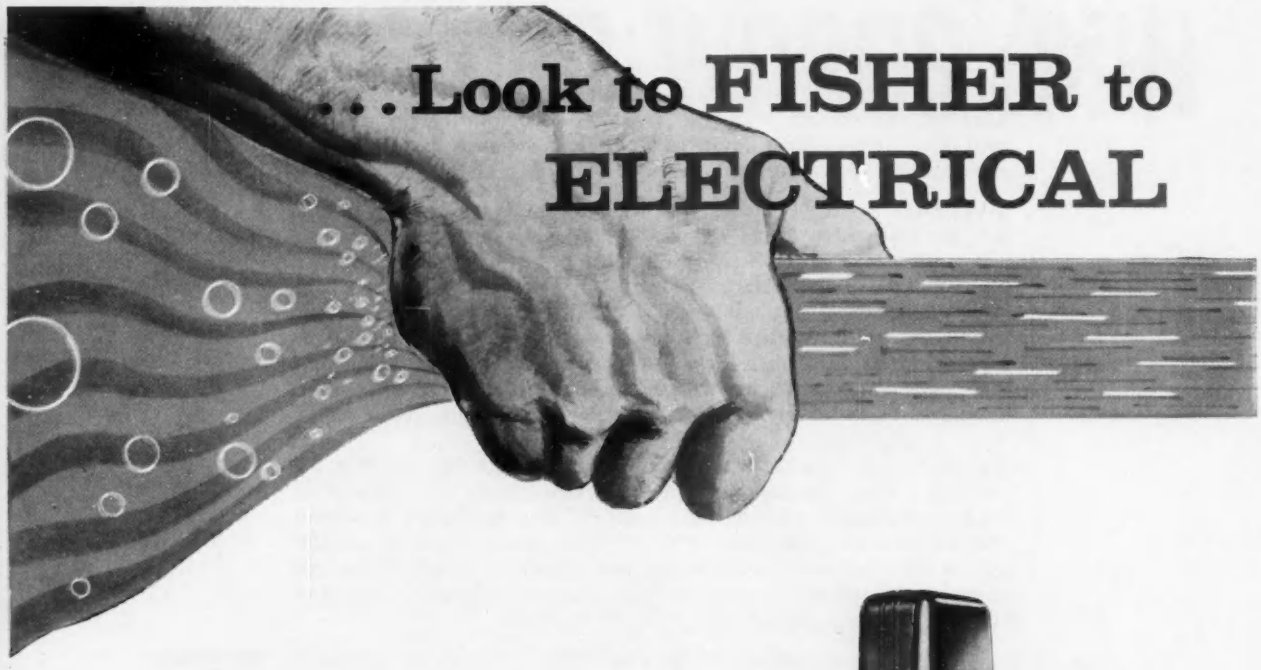
During fiscal 1959, the first year of the program, federal expenditures for vocational training were only $2.7 million, but that has increased to over $7 million in the current fiscal year. The administration has proposed the expenditure of $9 million for next year.

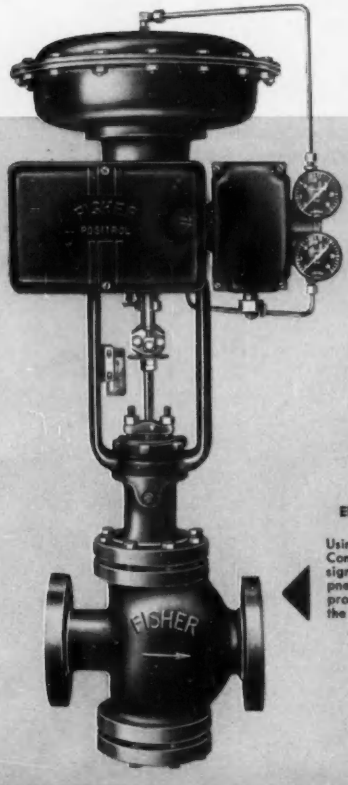
Student numbers

In the first year of the program, some 48,000 persons in 285 schools or institutions were enrolled in vocational courses aided by the Defense Education Act. The figure jumped to about 85,000 students in the second year. Not all of these, of course, were enrolled in measurement and control curricula. But there were enough to make a start to meet the predicted shortage of competent technicians in the instrument and control field.



...Look to FISHER to ELECTRICAL





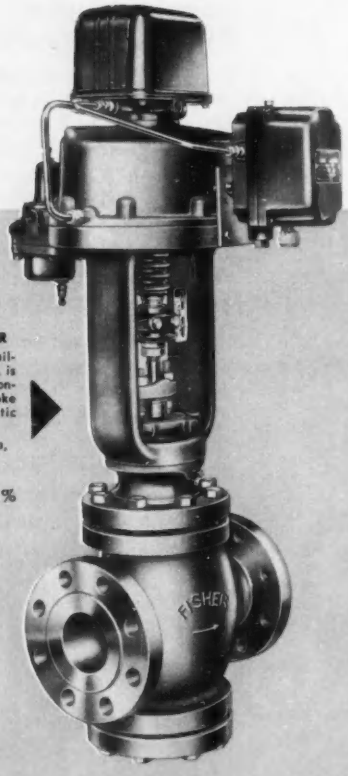
THE PNEUMATIC OPERATED PISTON "P.O.P." WITH ELECTRO-PNEUMATIC TRANSDUCER

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Input Current: 1 to 5 ma, 4 to 20 ma, 10 to 50 ma, d.c.

Linearity—1% of Full Range

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Using a conventional Fisher diaphragm Control Valve, the E-Positrol receives a Ma signal and translates this to a proportional pneumatic signal to a positioner which provides the speed and power to operate the valve.

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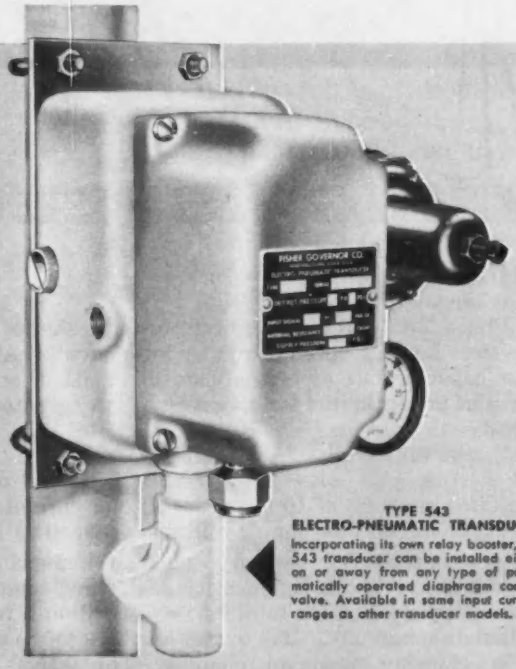


IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

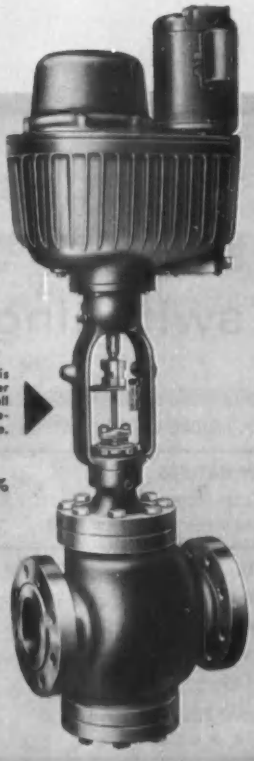
supply the muscles for your CONTROL SYSTEMS

The old adage, "a chain is as strong as its weakest link" can be equally applied to the "muscle" or more correctly the final control element on any control loop. The importance of a control valve in an electronic system should never be considered lightly and that is why you should look to Fisher for assurance in furnishing dependable and accurate control valves for your electrical or electronic system.

Described below are three types of actuators that offer an exceptionally practical and economical approach for control valves in electrical control loops.



TYPE 543
ELECTRO-PNEUMATIC TRANSDUCER
Incorporating its own relay booster, the 543 transducer can be installed either on or away from any type of pneumatically operated diaphragm control valve. Available in same input current ranges as other transducer models.

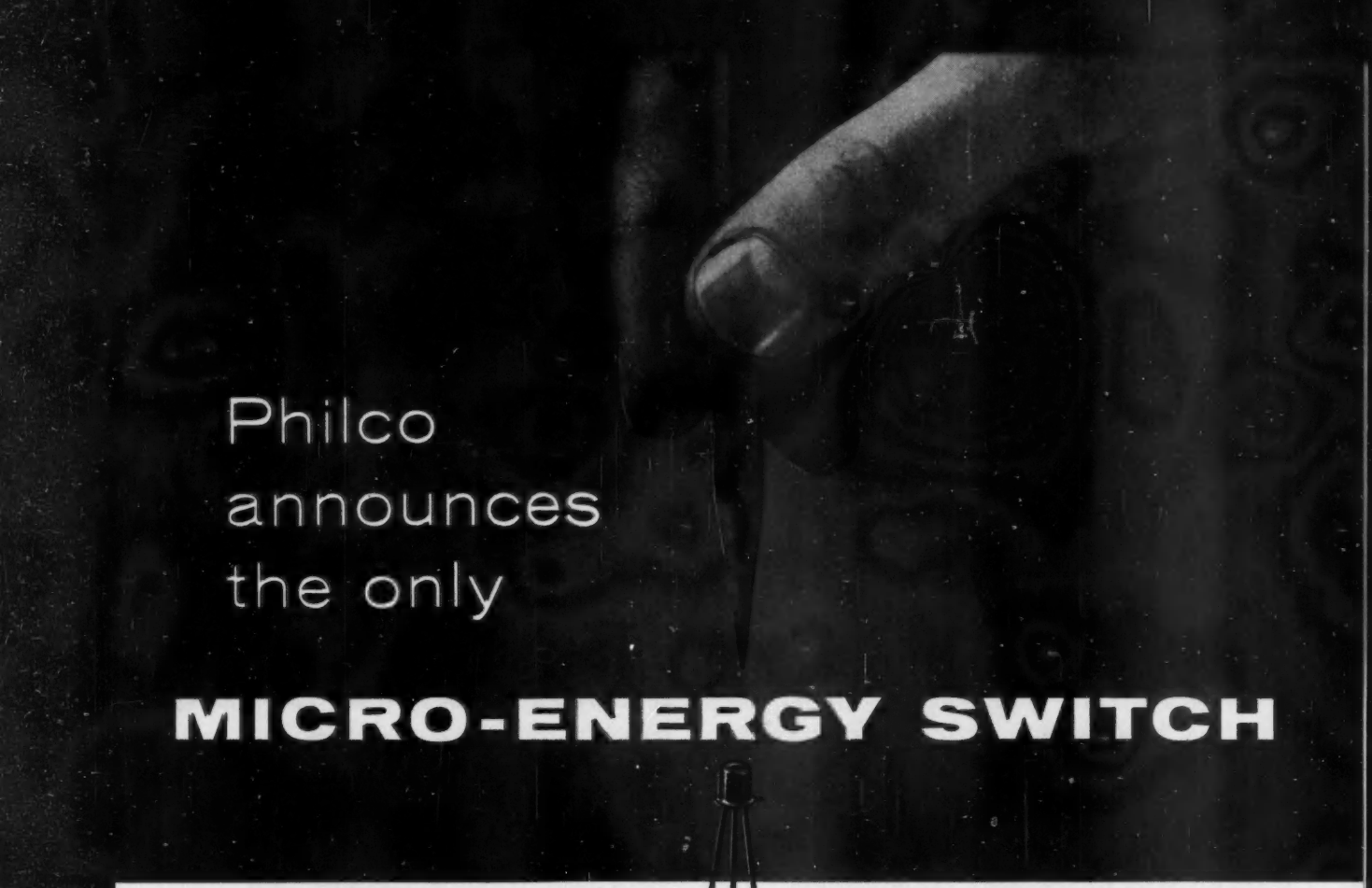


THE TYPE 330
ELECTRO-HYDRAULIC ACTUATOR
In electrical control systems where air is not available or desirable, the Fisher Electro-Hydraulic Actuator provides all the necessary requirements for a dependable and accurate control valve.
Maximum Stem Thrust..2000 pounds
Stroking Speed.....0.37 in./sec.
Resolution Sensitivity...less than 0.05%

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LOW ENERGY, HIGH SPEED
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T-1930 . . . MICRO-ENERGY SWITCH . . . TO-18 CASE			
MAXIMUM RATINGS			
Storage Temperature . . . . . 100° C			
Total Device Dissipation at 25° C . . 35 mw			
CHARACTERISTICS	**MIN.**	**TYP.**	**MAX.**
DC Current Amplification Factor, h_{FE} (V_{CE} = −0.20 v, I_C = −2 ma)	25	40	
Collector Voltage, V_{CE} (I_C = −2 ma, I_B = −0.2 ma)		.095	.13 V
Gain-bandwidth Product, f_T (V_{CE} = 1 v, I_C = 1 ma)	125	175	mcs

The Philco T-1930 is a new concept in the design of switching transistors for high speed computer logic circuits! All internal device capacities are exceedingly small . . . and its static characteristics are optimized for operation at low collector voltages and collector currents. *It permits the design of high-speed logic circuits with an overall power consumption only 1/3rd to 1/10th that of circuits with conventional transistors.* It will operate at pulse rates in excess of 10 mc with collector currents as small as 1 ma from collector supply voltages as small as 1 V.

This new micro-energy switch is of great importance in the design of ultra-reliable, high density, high speed equipment. In micro-energy circuits, the total device dissipation is reduced to an absolute minimum . . . 250 microwatts . . . a prime consideration in achieving maximum reliability. The T-1930 is an important step toward microminiaturization . . . permitting high packing densities without excessive internal heat generation. For complete information write Dept. CE-860.

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TRANSISTOR CENTER U.S.A.®

Control
ENGINEERING
AUGUST 1960

No Leapfrog Yet, but Look Out

Right after the International Federation of Automatic Control (IFAC) Congress began in Moscow, an Associated Press story appeared in U.S.A. newspapers. It reported that Western control experts attending the IFAC congress were "flabbergasted by Soviet achievements in automation." Continued the quotations, "We never dreamed this level had been reached." The AP story did just what it was intended to do: it made a big splash. Because it was sensational it got attention. Believing that the opinions expressed in the AP story were grossly inaccurate, we set about making a calm appraisal of Soviet automatic control work as it is now and as it may become. The true story is not frightening (see pages 24-27 for digests of cables from Moscow), but it does tell us that we must continue to push theory and application together, without letup.

At the Congress, theory was the Soviet forte, following naturally from the Communist conviction that proper theory precedes success in every political or scientific endeavor. But advanced control systems embodying the superb theoretical peaks were only in the prototype stage. None of the plants visited showed evidence of applying the theory or the few exciting prototypes. This was surprising and revealing, for practiced Western control engineers observed innumerable opportunities for applying well-understood control techniques let alone advanced systems. Soviet industry seemed to be awaiting a signal to fill the gaps between the peaks with practical control systems.

Now Gosplan headquarters has given the signal for a massive application effort, matching efforts in missiles and aircraft. The sparkling new Kiev Institute of Automation, with 2,000 engineers now and 6,000 by 1965, demonstrates the scale of the coming application effort. Soon there will be three additional application institutes. This is the way that a "rationally organized society" goes about the job of spreading the peak accomplishments. It does not rely on individual initiative, as does the Western economy, to continuously raise the mean achievement higher and higher. Absent will be the Western insistence on economic justification before attempting control installations. Increased productivity will be the only immediate Soviet goal.

By shaping theory and application together, we have steadily improved control across industry. Our high gain, wideband approach gives us a flexibility for leaps ahead from an already high level of application know-how. The Soviets have separated theory and application and will now try to pull up industrial control accomplishments from their low level in one fell swoop. "Leapfrogging" was the term used in one AP story. The leap has yet to come.

Derek Barlow



Safety Valve FOR AN ASTRONAUT

If America's first man-carrying rocket runs into trouble, a unique Donner device will play a vital role in bringing the Astronaut safely back to earth.

Known as a "maximum altitude sensor," the all solid-state system is essentially a fixed purpose miniature analog computer housed in a magnesium case only five inches long. Installed in the capsule, it goes into action if it is necessary to abort the rocket flight before the Astronaut's escape tower is jettisoned.

What it Does

The Donner device, which was developed for McDonnell Aviation with the approval of NASA, provides programmed time delay that operates rescue devices at maximum altitude.

Under abort conditions, the maximum altitude sensor provides output information which will:

1. Energize devices for firing the explosive bolts holding the escape tower onto the top of the capsule. This allows the escape tower to separate.

2. Energize the system which causes the escape tower jettison rocket to fire. With the tower separated, barostats are armed to open parachutes and furnish the Astronaut's capsule a safe descent.

Specialists in Analog & Digital Dynamics

Donner's maximum altitude sensor is another product from a firm specializing in the manufacture of accurate fixed and general purpose analog and digital systems designed to analyze, measure, and control inputs interlocking time, acceleration, jerk, velocity, and other dynamic inputs.

If you would like more information concerning our capabilities, contact your nearby Donner engineering representative or write us today.

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The System Characteristics of Modern Guidance Techniques

A special report coordinated by Dr. Charles J. Mundo, Raytheon Co.

1. System Aspects of Inertial Navigator Design

DAVID P. SARETT
Manager, Systems Engineering, Arma Div., American Bosch Arma Corp.

2. System Considerations for Guidance Radars

E. L. CHATTERTON
Head, Surveillance Projects Section, Arma Div., American Bosch Arma Corp.

3. Doppler Radar Techniques for Aerospace Navigation

BEN R. COLE
Consulting Engineer, Raytheon Co.

4. Modern Techniques in Celestial Navigation

DAVID B. NICHINSON
President, Kollsman Instrument Co.

5. Recognition in Perceptive Guidance Systems

CHARLES J. MUNDO
Manager, Systems Department, Advanced Development, Raytheon Co.

The requirements of the missile designer have been possibly the greatest single stimulus for the rapid advancements in control systems engineering over the last 10 years. Thus it is particularly appropriate that CONTROL ENGINEERING should report on the guidance art. Basically there are two approaches to guidance: perceptive systems, where the destination is directly observed by the guidance sensors and extrapolative systems, where the location of the destination relative to the vehicle is stored in a memory within the vehicle and the sensors of the guidance system measure the dynamics of the vehicle. Perceptive systems are typified by the intercept and terminal guidance methods for guided missiles like the Sidewinder, Hawk, Sparrow, and Falcon. The main problem in such cases lies in seeing the destination in the presence of noise or background interference. Extrapolative systems are used almost exclusively in ballistic vehicles like the Atlas and Minuteman where guidance is accomplished by establishing the dynamics at the origin of the flight so that it intercepts the target.

The Doppler systems discussed by Cole and the inertial systems discussed by Sarett are representative of extrapolative systems. The radio guidance systems discussed by Chatterton can be either extrapolative or perceptive depending upon the nature of the guidance problem. The celestial systems described by Nichinson are perceptive in nature although they do not see the destination directly—they see a star map directly correlated to it and navigate by this star map. Directly perceptive systems are discussed in the final article which outlines the development of the perceptive science and points to the perceptive system of the future which will have cognitive properties.

System Aspects of Inertial Navigator Design

DAVID P. SARETT, *Arma Div., American Bosch Arma Corp.*

Inertial navigation is a special form of dead reckoning which in the ideal case is the only navigational system which can be placed in an entirely self-contained "black box". Inertial navigation systems are nonradiating and independent of ground facilities; these represent great military advantages over other systems.

With the lifting of security restrictions on certain aspects of inertial navigation during the past few years, a number of excellent discussions of the subject have been published (Refs. 1, 2, 3), as well as detailed discussions of components (Refs. 4, 5, 6). But there is a residue of vagueness which has led to misconceptions about the theory and performance of inertial systems.

The basic problem

In inertial systems, position is calculated with respect to a chosen coordinate frame from the laws of motion and measured vehicle accelerations. The fundamental problem in inertial systems results immediately from the Theorem of Equivalence, according to which any instrument designed to respond to inertial forces (such as an accelerometer) must also be affected by gravitational fields. The output of an accelerometer could therefore be interpreted as the vehicular acceleration it was intended to measure when the vehicle was in reality stationary in an unknown gravitational field.

This dilemma resolves easily when the gravitational field is known, as in the vicinity of the earth. For most practical purposes the vector direction and magnitude of the earth's gravitational field (in conjunction with the centripetal acceleration due to the earth's rotation) are associated with the local plumb-bob vertical and altitude. By referencing the gravity vector to the particular coordinate frame in which the vehicle motion is to be computed, the data necessary for navigation can be derived.

These considerations establish "tracking the vertical" as fundamental to terrestrial inertial navigators, regardless of system mechanization or component design. Moreover, they establish that inertial navigation in an unknown gravitational field is impossible. Thus, there are three fundamental requirements which necessarily precede the design of any specific system for inertial navigation as given in the box.

The elusive vertical

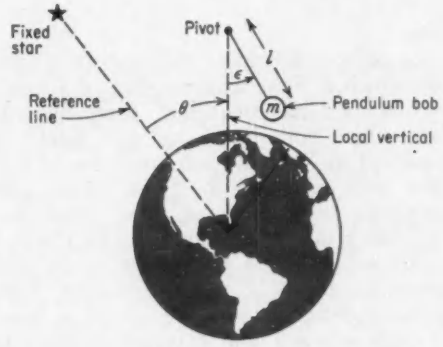
For an inertially guided vehicle flying over the surface of the earth, the gravity vector of importance is the local vertical moving with the vehicle. The motions of the vehicle become, in effect, the motions of the local vertical. Early investigations into the mechanics of vertical tracking were made by Dr. M. Schuler, who was concerned with ships' gyrocompass errors caused by pendulum deflections in the presence of north-south accelerations (Ref. 7). The pendulum which was the vertical sensor of the gyrocompass was responding to the vector sum of the horizontal acceleration and gravity. Schuler's analysis, Figure 1, showed that a simple pendulum of length l equal to the earth's radius R will be insensitive to horizontal accelerations of its pivot over the surface of the earth. In other words, the so-called Schuler-tuned pendulum will remain aligned with the local vertical no matter how moved about, thus it is an ideal inertial navigator vertical reference.

Fundamental Requirements for Inertial Systems

There are three fundamental requirements which must be satisfied in any inertial navigational system:

1. ***A frame of measurement of acceleration must be selected and maintained in a known orientation. The measurement frame need not remain fixed in inertial space, but its orientation must be explicitly known at all times.***
2. ***A frame of computation (such as earth-fixed latitude and longitude) must be selected with known spatial and time relationships to the measurement frame.***
3. ***A means must be provided for determining the gravitational field vector relative to either of these frames at any time.***

Heeding these requirements, inertial systems can be designed for navigation using gyros, accelerometers, and computers and may include means for inserting or extracting navigating data.



SCHULER TUNING

Driving torque — Σ (Pendulous torque + Inertia torque) = 0

$$-\ddot{\theta} m l R - \left[mgl\epsilon + J(\ddot{\epsilon} - \ddot{\theta}) \right] = 0$$

For a simple pendulum, $J = ml^2$

$$\ddot{\epsilon} + \frac{g}{l}\epsilon = (1 - \frac{R}{l})\ddot{\theta}$$

and if $l = R$ (Schuler tuning), then:

$$\text{or} \quad \begin{matrix} \ddot{\epsilon} + \frac{g}{R}\epsilon = 0 \\ (s^2 + \omega^2) E(s) = 0 \end{matrix}$$

$$\omega = \sqrt{g/R}, \quad T = \frac{1}{\omega} \cong 84 \text{ min}$$

FIG. 1. Schuler's analysis of pendulum errors that lead to principle of Schuler tuning.

A physical pendulum can never be built with the dimensions required for Schuler tuning—the period at the earth's surface must be approximately 84 min. But feedback servosystems can be made which are oscillatory with the Schuler period (Ref. 8), and such servos are characteristic of every inertial navigator that has been designed.

Inertial instrumentation

The space-fixity characteristics of gyroscopes are well documented, well understood phenomena—a spinning wheel with momentum H will tend to hold its direction in space, unless acted upon by an external torque T. The familiar gyroscopic (vector) equation $T = \omega H$ relates the momentum, torque, and resulting precession rate ω. Current working designs are categorized primarily by the manner and extent of restraint of the gyro wheel gimbal. If only a single degree of freedom (SDF) is allowed for gyro precession, elastic restraint by springs or torque feedback produces a rate gyro, and viscous restraint by a fluid produces an integrating gyro. With two degrees of freedom (TDF), a gyro is merely a "space synchro".

In the SDF case, rotation around the output (precession) axis can exceed rotation of the gyro case around the input axis, giving, in effect, an "angular gain". Rotation of the gyro case orthogonally to the spin axis causes a torque reaction on the member to which the case is fixed. Cross-coupling can occur when the gyro is rotated around its output axis.

In the TDF case, rotation of the case will not result in precession or torque reactions or cross-coupling since the gyro is unrestrained. Torque reactions are useful for platform base motion isolation; cross-coupling can be bothersome. More sophisticated considerations are in References 5 and 6.

The pure theory of gyroscopics is little comfort to the gyro designer who must face the fact that a mass shift of 1 microin. in a 1 million gm-cm²/sec wheel will produce a drift rate of 0.1 deg per hr (6 nautical mph on a great circle route) in a 1-g field. Considering the very many potential sources of gyro error (unbalances, shifts, magnetic and elastic effects, temperature, anisoelasticity) today's inertial grade gyros are modern engineering miracles, made under ultra-sanitary controlled conditions.

Accelerometers are even simpler in concept, but only great care and ingenuity have led to the precisions demanded by inertial systems. The art has produced, however, accelerometers containing one and two stages of integration for velocity and distance meters (Ref. 4).

The basic functions of gyros fall into several categories, and the extent to which they can accurately perform these functions determines to a large degree the choice of system mechanization:

- When coupled to a servo driven gimballed platform, the gyro helps form a base motion isolation system for accelerometers. The gyro platform thus might be the measuring frame for acceleration data. In this function the gyro is a short-time memory of a reference direction for the inertial system. Except for negligible servo errors, the rotation of the vehicle about its own axes (roll, pitch, yaw) is decoupled from the measuring system. Inertial space long-term memory may also be obtained with a stabilized platform. The gyros need not be torqued, except perhaps to account for systematic drift torques which are acceleration sensitive and acceleration squared (g^2) sensitive. Accelerometers on such a platform read gravity components and must have wide range and high linearity.
- The gyro and a servoed platform can be torqued with precession signals to yield a platform rate proportional to the torquer signal magnitude. The gyros must be torqued with vehicle rates and components of earth's rate to accomplish accurate positioning of the measuring frame. In this function the gyro assumes the role of a "black box" with nearly perfect integrator properties and is used accordingly in instrumentation design. Accelerometers read components normal to gravity only, and range and linearity problems are less severe.
- Strapped down to the vehicle, the gyro can yield the necessary information concerning the motion of the vehicle in inertial space. Accelerometer data can then be computed. In this function the gyro merely acts as a transducer and, together with the

strapped-down accelerometer, is subjected to severe shock, vibration, and acceleration environments.

System mechanizations

The various mechanizations of complete inertial systems are in a sense merely permutations and combinations of the possibilities in the transducing and handling of component data. Many names have been applied to these mechanizations, and the ones listed in Table I are functional. Table I shows that each type of mechanization has advantages and disadvantages. The final choice of a particular mechanization depends on the effects of component inaccuracies on system performance as well as on the nature of the application (duration of mission, velocity, and acceleration profile).

Inertial system analysis

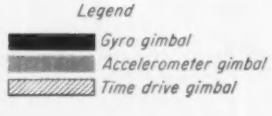
Basically, the relationships of the accelerometers to the vertical determine the functional block diagram which is most representative of a mechanization. If the "high frequency" components of motion (vehicle roll, pitch, and yaw rates) can be considered satisfactorily accounted for in the computer (strapdown) or by servo driven platforms (geometric, semianalytic, analytic), then the functional block diagrams break down into two classes: A—systems, in which the vertical exists physically (geometric, Figure 3, and semianalytic, Figure 2) and B—systems, in which the vertical is "phantom" and exists only as a number or voltage in a computer (analytic and strapdown, Figure 4).

Note that the closed loops have similarities which are independent of mechanization:

- In each the performance operator is reciprocal to the driving function.
- Each has an oscillatory characteristic at the Schuler frequency.

TABLE I
CHARACTERISTICS OF INERTIAL SYSTEMS

System	Gyros	Accelerometers (Range computation only)	Comments
GEOMETRIC	2 TDF or 3 SDF gyros	2 accelerometers	Large package, virtually no computer. Has been flown in long term flights, and tested on ships.
(space-oriented platform)	Gyros fixed in inertial space and tumble with respect to gravity.	Accelerometers read components normal to gravity on Schuler tuned platform.	
5 gimbals			
SEMIANALYTIC	2 TDF or 3 SDF gyros	2 accelerometers	Small package. Simple computer. Has been utilized in short term flights, and in subs.
(torqued vertical, local level)	Gyros torqued at vehicle and earth's rate. Fixed with respect to gravity.	Accelerometers read components normal to gravity on Schuler tuned platform.	
3 (or 4) gimbals			
ANALYTIC	2 TDF or 3 SDF gyros	3 accelerometers	Small package. Complex computer. Has flown in ballistic flight.
(phantom vertical, nonlevel)	Gyros fixed in inertial space and tumble with respect to gravity.	Accelerometers read gravity components — must be corrected. Require wide range and high linearity.	
3 (or 4) gimbals			
STRAPDOWN	3 SDF gyros	3 accelerometers	Smallest package. Highly complex computer.
(no platform)	Gyros tumble with respect to gravity. Must provide instantaneous rates to computer.	Accelerometers read gravity components and additional coriolis terms —must be corrected. Require wide range and high linearity.	Under design.
No gimbals			

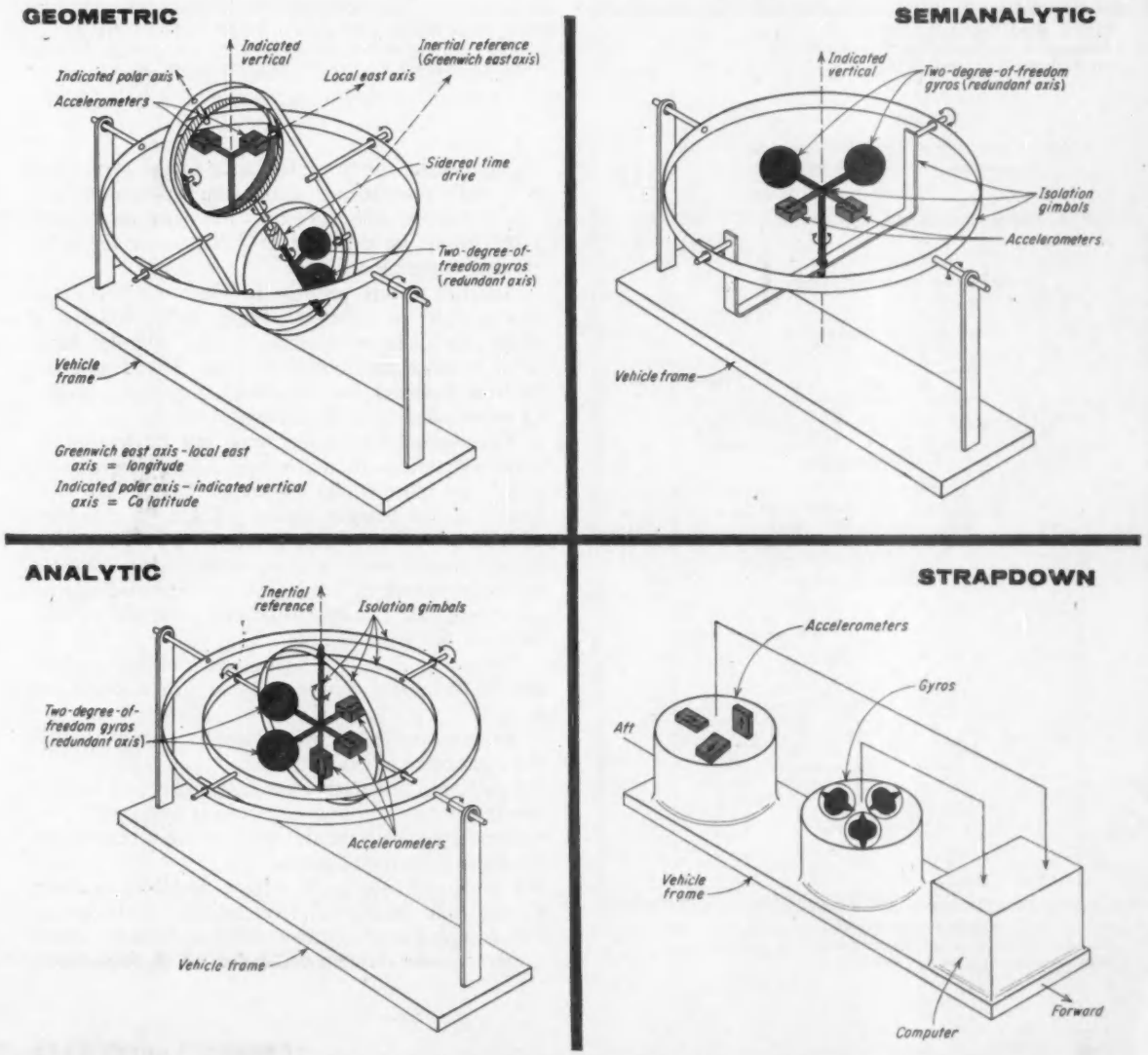


Errors in computation of position can be determined by introducing system error sources as driving functions, Figure 5. (The block diagram of Figure 2 has been used for this analysis, but Figure 3 or Figure 4 could have been analyzed similarly). Kinematic inputs have been omitted.

As can be seen from Table II, accelerometer bias and platform misalignments (due to servo hangoff or improper mechanical adjustments) yield similar error functions. This might be expected from the fact that the system once freed of external alignment equipment cannot distinguish between the two. A misalignment of 30 sec of arc or an accelerometer bias of 1.45×10^{-4}g will independently cause 1 nautical mile of peak error approximately 42 min after the error is introduced. Scale error is a function of the input and cannot be calculated easily unless the acceleration profile is known. With an abrupt change of 1,200 ft per sec ("abrupt" relative to the Schuler period), a 0.1 percent accelerometer will produce approximately 1/6 of a mile peak error 42 min after the acceleration impulse.

Gyro drift is the only unbounded error. A constant gyro drift of 0.0167 deg per hr leads to an average error rate of 1 nautical mph plus a sinusoidal platform tilt of 13.4 sec maximum. Thus, long-time accuracy depends almost solely upon stable gyros. Fortunately for inertial system designers constant gyro drift in one direction hardly ever occurs in practice, and the inertial system gets a chance to do some statistical averaging in long-time applications.

Gyro torquing inaccuracy is another important source of error (not shown in Table II). In semianalytic systems the gyro must be torqued so that the platform remains aligned to the local vertical. In addition, components of earth's rate must be counter-balanced by torquing which is variable with geographic position. Since distance is computed



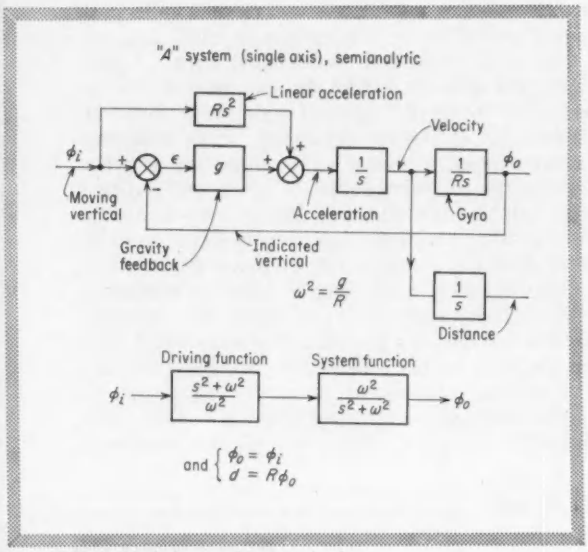


FIG. 2. Block diagram for one axis of semianalytic system in which the vertical exists physically (system II, Table I).

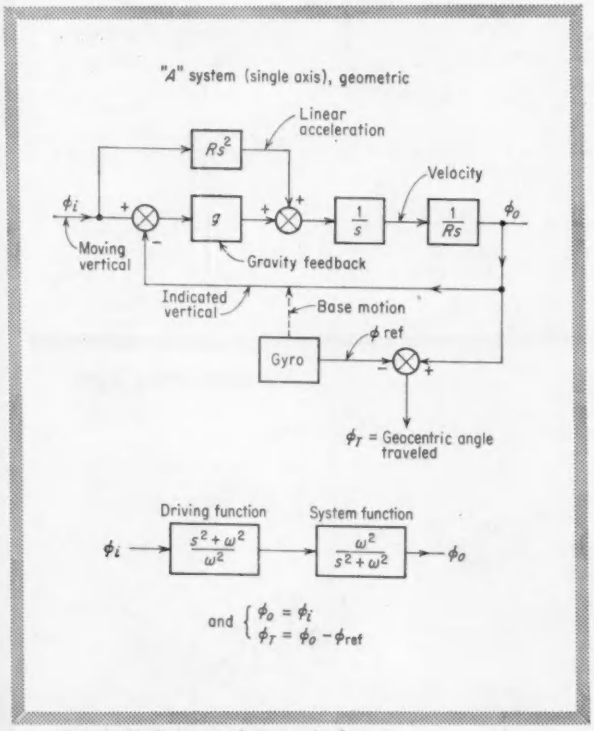


FIG. 3. Block diagram for one axis of geometric system in which the vertical exists physically (system I, Table I).

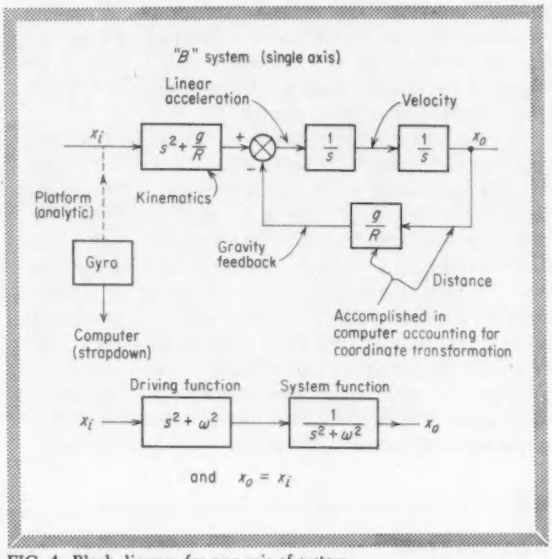


FIG. 4. Block diagram for one axis of system with computed or phantom vertical (system III, analytic, or system IV, strap-down, Table I).

by integrating the torquing signal to the gyro, there is virtually a one-to-one relationship between torquing inaccuracy and distance error. For example, a 1-mile error would be expected in 1,000 miles for a 0.1 percent torquing accuracy.

Another feature peculiar to the semianalytic system is that, in its most popular mechanization, it computes distance external to the Schuler loop. Thus distance-integrator drift errors are not modified by loop feedback and constitute a potential source of unbounded error similar to gyro drift.

The distance error functions can be treated by series expansions to derive approximate expressions which are more useful for times shorter than one-fourth of the Schuler period. Table III compares the distance error expression forms. For short missions accelerometer errors replace gyro errors as the chief source of headaches for inertial designers since gyro data can be exceptionally stable and well-behaved for short periods.

Figures 6, 7, and 8 summarize the quantitative aspects of inertial component errors on a single-axis basis.

There is no one "optimum" inertial system, though the signposts are evident:

- A preferred orientation for both gyros and accelerometers is nontumbling with respect to gravity.
- A preferred instrumentation is to avoid continuous precision torquing of gyros.
- A preferred coordinate system choice is to avoid Coriolis and centripetal accelerations which necessitate complex accelerometer data corrections. None of the systems shown combine all of these features!

A particular design must consider reliability, cost, weight, space, and availability of components as well as preference for system mechanization. The goals of the mission (particularly its duration) are extremely important in determining an optimum design.

The heading problem

The analyses and mechanization just described have all but ignored the heading problem, whereas it is actually one of the more formidable problems in the field of self-contained navigation. Accurate ballistic systems presently rely upon optical azimuth alignment prior to launch. Gyrocompassing has been used in some applications and for true self-containment has greatest appeal. But it also has drawbacks. With the appearance of new gyros of high stability and torquing accuracy, however, the gyrocompass will command greater attention for both ground and airborne use (with Doppler).

Errors due to azimuth misalignment at launch can be approximated by range times azimuth error (in radians). The leads to the conclusion that 1 min of arc will cause 1 mile of error in a 3,440-mile flight, indi-

TABLE II – ERROR SOURCES IN INERTIAL SYSTEMS

	Error source	Error transform	Distance error transform	Distance error time function
E_1	Accelerometer scale – impulse	* δ	$\frac{\delta}{s^2+\omega^2}$	$\frac{\delta}{\omega}\sin\omega t$
E_2	Accelerometer bias – step	$\frac{\Delta A}{s}$	$\frac{\Delta A}{s(s^2+\omega^2)}$	$\frac{\Delta A}{\omega^2}(1-\cos\omega t)$
E_3	Constant gyro drift – step	** $\frac{GR}{s}$	$\frac{GR\,\omega^2}{s^2(s^2+\omega^2)}$	$GR\left(t-\frac{1}{\omega}\sin\omega t\right)$
E_4	Platform misalignment – step	$\frac{\epsilon_0}{s}$	$\frac{\epsilon_0 g}{s(s^2+\omega^2)}$	$R\epsilon_0(1-\cos\omega t)$

* δ is taken as percentage of velocity change in a short time period. (If scale error is 0.01 percent, then $\delta = \Delta V \times 10^{-4}$.

** G is gyro drift rate; i.e., angle per unit time. GR is step at velocity level in semianalytic diagram.

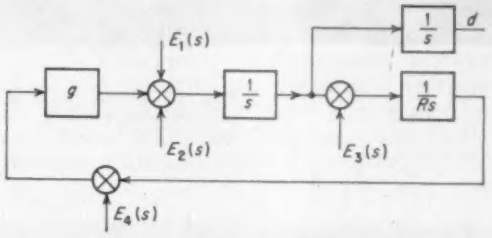


FIG. 5. Block diagram of Figure 2 with system error sources as inputs to determine errors in position computation.

LONG TERM ERRORS

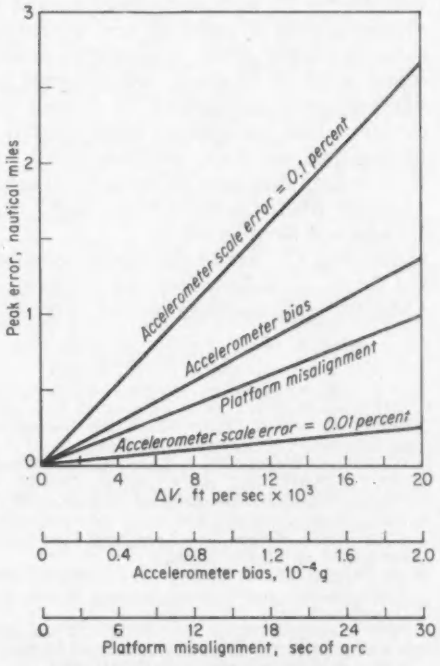


FIG. 6. Long term inertial errors due to three sources shown on curves.

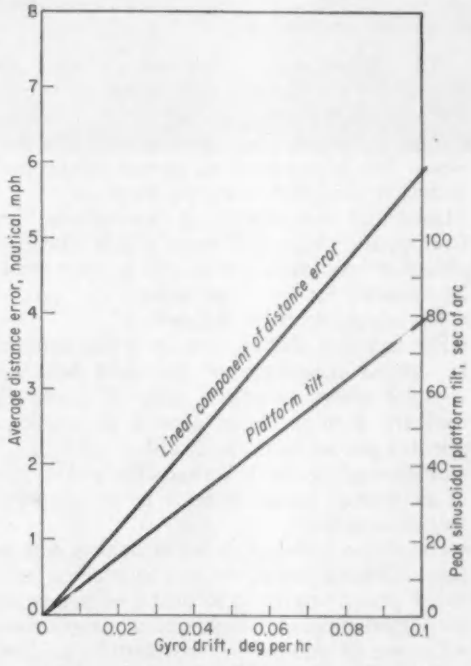


FIG. 7. Long term gyro drift errors assuming continuous drift in same direction, which is very unlikely.

SHORT TERM ERRORS

TABLE III - SHORT TERM INERTIAL ERROR FUNCTIONS

Error	Complete function	Short time approximation
E_1	$\frac{\delta}{\omega} \sin \omega t$	δt
E_2	$\frac{\Delta A}{\omega^2}(1-\cos \omega t)$	$\frac{1}{2}\Delta A\, t^2$
E_3	$GR(t-\frac{1}{\omega}\sin \omega t)$	$\frac{1}{6} gG\, t^3$
E_4	$R\epsilon_0(1-\cos \omega t)$	$\frac{1}{2} g\epsilon_0 t^2$

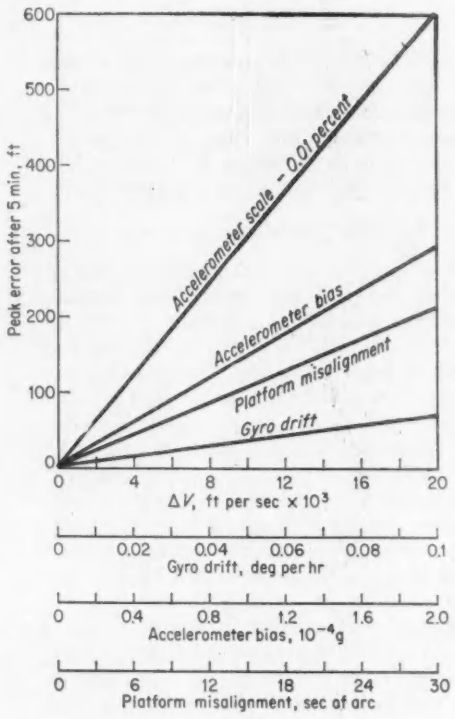


FIG. 8. Short term (5-min) inertial errors including gyro drift. Compare with Figure 6.

cating the seriousness of the situation for long range flights. Gyro drift during flight will lead to an equivalent misalignment of one-half the gyro drift rate times the time of flight (if the azimuth axis is cast free in inertial space).

Practical problems

Many complications lurk beneath the surface of a subject as broad in scope as inertial navigation. These complications will not be analyzed because they do not add to understanding of the fundamental ideas. But in practice they present serious problems to system designers. Among them are:

- Unwanted components of acceleration, such as Coriolis and centripetal terms which arise from the choice of coordinate system and in most cases must be corrected for by computation.
- The nonsphericity of the earth.
- The fact that altitude usually is not determinable by inertial means except for short time periods. (System errors propagate without limit when a feedback loop is closed around an accelerometer oriented parallel to the vertical.)
- Cross-coupling effects between the various channels of an inertial navigator must be accounted for in long-time systems.
- The choice between digital or analog instrumentation. (Analog computers are conceded to be limited to 0.1 percent accuracy, so digital instrumentation is the logical choice for high accuracy applications.)
- The use of internal instrumentation to damp system oscillations requires external data to remove forced dynamic errors caused by damping.

Trends in inertial development

Current research and development efforts in inertial work are concerned with:

- Improving component design so that super-accurate components can be mass-produced cheaply and easily.
- Seeking breakthroughs in new components, such as nuclear spin gyros; piezoelectric accelerometers; liquid-metal, electrostatic, and cryogenic gyros.
- Investigating applications of inertial systems to extraterrestrial navigation, where special problems of long-time operation, very low thrust, and loss of Schuler loop gain (due to low gravity) are found.
- Uniting inertial systems with "aids" like celestial trackers and Doppler radars.
- Increasing the role of the digital computer in inertial design as evidenced by the "phantom" systems.
- Miniaturizing complete inertial systems.

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System Considerations for Guidance Radars

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In missile guidance applications the associated radar systems may be classified by application as in Figures 9, 10, 11, and 12.

Command guidance radars

Command guidance is particularly attractive for ballistic missile applications, antiballistic missile systems, or ground-to-air missiles. In the ballistic missile case the radar outputs required must be determined from the known missile characteristics. Since extreme accuracies are required, range, angle, range rate, and angular rate may all be required at accuracies that approach state of the art limitations. The maximum guidance range required is a function of the missile design but would generally be on the order of a few hundred miles. The physical environment of the radar would be the ground, and the design would be based on this environment with a high degree of freedom in size and weight, Figure 9.

The long ranges involved indicate that the signal to noise ratio is a prime problem in systems of this type. Requirements for extended range radars have resulted in intensive research to reduce the internal noise of the radar receiver. This research has resulted in the development of masers, parametric amplifiers, and improved crystals. Table IV illustrates the degree of improvement obtainable with these devices as compared to radars of 1955.

While the increase in range indicated for masers or parametric amplifiers is attractive, the final receiver design must consider other factors. Broadband parametric amplifiers exist today, and the application of traveling wave techniques may eventually result in broadband masers, but the requirement for variable frequency pumping oscillators and cryogenic devices complicates the design. Unless serious restrictions are placed on antenna size, it would be simpler to achieve the desired range through an increase in antenna dish size. An added consideration is the fact that the antenna reflector is not subject to failure. Assuming the use of a well-matched modern crystal mixer with a noise figure of 8 db and a 10-ft diam antenna achieved the 112-mile range used in the example above, theory shows that at the same transmitter frequency an 11.8-ft dish would achieve the same range increase as would the addition of the rf amplifier. Similar reasoning indicates that a 13-ft dish would be equivalent to the parametric amplifier, and a 13.6-ft dish would be equivalent to the maser. Where serious restrictions exist on antenna size or on transmitter power, or where maximum possible ranges are required, the parametric amplifier or maser provide the means to extend range capability.

• **Angle tracking.** Several means exist for establishing the angular position of the missile. The simplest and most direct is to measure the antenna angular position at which an echo is received from the target. Since narrow beam antenna patterns generally have a $(\sin x)/x$ characteristic, there is relatively little amplitude variation across the beam, so resolution of such a system is limited to the antenna beamwidth.

To improve the resolution of the antenna, the

TABLE IV—RECEIVER IMPROVEMENTS INCREASE RADAR RANGE

Receiver	Approximate noise figure	Comparative range
Standard 1955 techniques	10	100
Improved mixer and crystal design	8	112
Traveling wave RF amplifier	5	132
Parametric amplifier	2	156
Maser	0.5	170

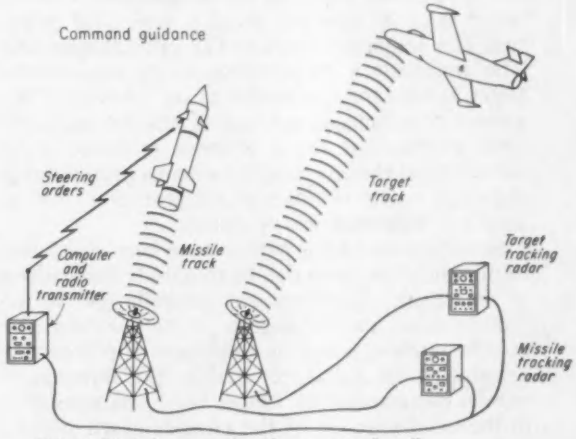


FIG. 9. Typical command guidance system has all radar and radio communications equipment on ground.

FIG. 10. Typical active homing system requires a track radar (transmitter-receiver) and computer in the missile. Search radar is used prior to launch.

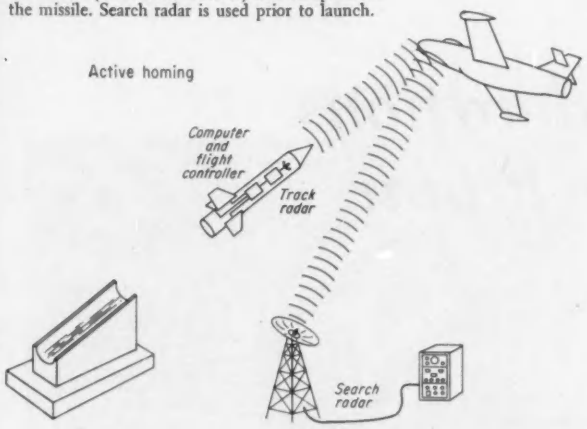


TABLE V – RADAR RANGE OF ACTIVE HOMING SYSTEMS

	Small missile	Large missile
Antenna Diameter — in.	6	15
Frequency — Mc	33,000	4,400
Antenna Gain — db	32	28
Peak Power — kw	10	250
Pulse Length — microsec	5	5
Repetition Rate — cps	1,000	1,000
Receiver Bandwidth — kc	300	300
Noise Figure — db	8	8
Target Area — sq meters	10	10
Resultant Range — nautical miles	19	50

center of the beam may be programmed in a circle around the target. When the target is in the exact center of the circle, the echo will be less than the echo received when the target is in the center of the beam and will be constant regardless of the instantaneous position of the beam. When the target is not in the exact center of the programmed antenna circle, the echo returned shows a modulated amplitude at a frequency equal to the antenna spin rate. The amplitude is proportional to the amount the target is off center, and the phase relative to the known instantaneous position of the antenna indicates whether the target is above or below or to either side of the center of the antenna programming circle. A system of this type is known as a "conical scan" or sequential lobing system.

Simultaneous lobing systems have been developed to minimize the noise due to amplitude fluctuations of the target. These systems generally use two or four antennas, and the angular position of the target may be resolved either by amplitude or phase comparisons of the signals received by the antennas.

• **Order communication.** Orders to be communicated to the missile are set by the missile's characteristics and instrumentation. The command link is a pure communications problem and must be analyzed as such in terms of number of channels required, security coding of signals, and redundancy. The missile tracking radar signal may be modulated by variation of repetition rate, pulse width, pulse amplitude, or carrier frequency coded to transmit orders to the missile. Elaborate coding techniques which may involve simultaneous transmission at several different frequencies may be employed to prevent an enemy from deflecting or destroying the missile.

Active homing

The active homing missile guidance system is the antithesis of command guidance since the prime consideration in the latter case is to keep maximum complex equipment on the ground and leave the missile relatively unencumbered with electronic gear. The active homing missile carries sufficient radar to home on the target by itself, Figure 10.

In the command guidance case a slight angular bias error may result in a disastrously large miss-distance in a long range missile. Bias errors are relatively unimportant, however, in active homing missiles, since the equivalent miss-distance steadily decreases as the missile approaches the target.

A second advantage of active homing guidance is that where widely separated multiple targets exist, several missiles may be launched simultaneously, provided the targets have been delineated by means of a parent search radar.

Disadvantages of the technique are that the electronics must be kept to a minimum to avoid overburdening the missile. Generally the antenna is relatively small, so angular resolution and range capability are limited and only simple antijamming techniques may be used. Thus the missile is relatively easy to jam and requires a well defined radar target.

These considerations indicate that the active homing missile is most suited for ground-to-air or air-to-air missions particularly where multiple target conditions may exist. Active homing may be used air-to-ground where the radar target is well defined.

To determine the range capability of active homing missiles, consider two hypothetical missiles—one of a relatively small air-to-air type in the 8-in. diam class and the second, a larger missile in the 18 to 20-in. diam class. Representative radar parameters are listed in Table V. The range figures are optimistic since they neglect certain minor losses and do not allow sufficient signal to noise ratio to permit simple automatic tracking circuitry. Adding 12 db losses to account for these losses plus other deteriorations due to field maintenance conditions reduces the ranges shown in Table V by a factor of two to nearly represent the true conditions.

Semiactive homing

The semiactive homing missile depends upon an auxiliary radar usually located at the missile launch point to illuminate the target, Figure 11. The missile contains only a radar receiver and extracts its

information about target position from the auxiliary radar beam. Various means exist for instrumenting the system. One method is to have the missile receiver sense the scan pattern and adjust the missile to keep it in the center of the scan pattern. In this case the receiving antenna of the missile does not scan and is aimed toward the mother radar transmitter. A second method is to have the mother radar illuminate the target with a steady beam and let the missile radar detect the echo from the target. In this case the missile radar antenna may be either a sequential or a simultaneous lobing antenna.

The system contains all the elements of a command guidance system, and it is possible to derive a multimoded capability such that the missile may function as a beam rider or a command guidance device and may also have a capability of homing on the target defensive radar or the target's jamming equipment. This multitude of possibilities makes this technique particularly attractive in a strong jamming environment since redundant communication links may be readily made available.

Considering the small missile given as an example in the active homing discussion, the mother radar might easily operate at 250 kw and could well use a 24-in. dish. The missile range would then be almost three times as great as for active homing. As in command guidance, the mother radar must be committed to a single target.

Passive homing missiles

Passive homing missiles are equipped with a radar receiver and a sequential or simultaneous lobing antenna, Figure 12. The receivers extract positional information from enemy radar radiations and home on this information. The situation is somewhat analogous to the beam rider homing on the signal reflected from the target except that the frequency of the radiation is under the control of the enemy. The simplest configuration for a receiver of this type consists of a broadband antenna followed by a crystal detector which converts received microwave energy directly to video frequency information. While the antenna and detector should have very wide bandwidths since there is only gross knowledge of the possible range of frequencies of enemy radars, the bandwidth of the video amplifier and error sensing channels need only be wide enough to pass the narrowest pulse expected in the target radar.

The passive guidance radar receiver can be designed with very long range capability since it is receiving a directly radiated signal rather than a reflected one. In this case the signal received varies inversely as the square of the range rather than the inverse fourth power as used in the radar equation. While some of the range advantage is lost due to inherently poorer signal to noise ratios obtainable in crystal video receivers as compared to superheterodyne receivers, it is still possible to get ranges on the order of five times the range of an active homing missile. This calculation is based on the assumption that the radar transmitters have equal powers under the two conditions.

The passive homing missile is extremely difficult to jam, since it may be designed to home on most jammers as well as on radar signals.

A natural application for this type of missile is as an air to ground offensive missile to eliminate enemy ground radars or as an air-to-air defensive missile against radar directed attacks.

Choosing the right radar

Using these basic design tools and techniques it is possible to reduce the various combinations of parameters to an efficient design. The first requirement is an adequate definition of the problem. Table VI gives general information about the design areas most directly affected by system requirements. The table indicates that certain trade-offs are usually necessary, particularly between such basic considerations as size and weight restrictions set by an airframe and long range and high accuracy requirements.

Practically all radars may be grouped according to modulation technique under one of the following three classifications:

1. Continuous wave (no modulation)
2. Frequency modulation
3. Pulse amplitude modulation

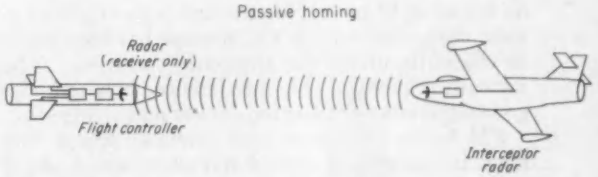


FIG. 11. Typical semiactive homing system has only radar receiver in missile, with antenna oriented to ride beam of mother radar or to home or reflected signals from mother radar.

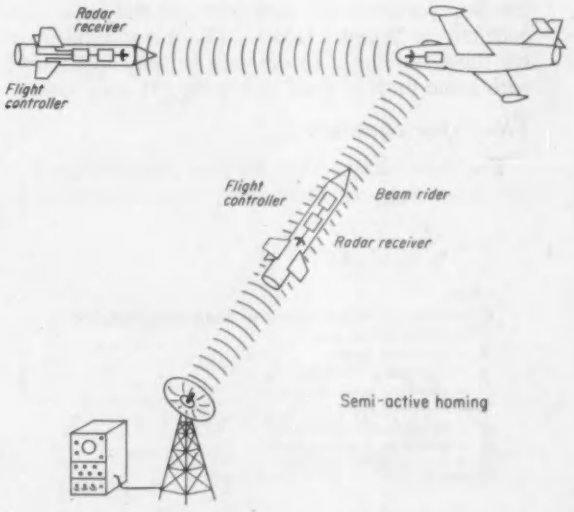


FIG. 12. Typical passive homing system has only radar receiver in missile, is designed to home on radio, radar, or jamming radiation from enemy target.

TABLE VI – HOW GUIDANCE SYSTEMS REQUIREMENTS AFFECT RADAR

Information Required	Design Area Affected
Radar Outputs Required	
Range	Parameters of the radar equation Sophistication of information theory applications Circuitry design for extracting information
Angle	Antenna design for lobing techniques Circuitry design for extracting information
Range rate	Possible use of Doppler techniques Circuitry design for extracting information
Angular rate	Circuitry design for extracting information
Display	Information theory techniques to establish optimum signal to noise Human engineering principles to facilitate interpretation
Accuracy required	Circuitry refinement required Size of antenna required to resolve angle
Radar Environment	
Noise environment	Antijam circuitry Information theory techniques for compatibility with other radiations within the environment Information theory techniques to separate signal from ground clutter or random noise
Physical environment	Size and weight limitations for airborne gear Environmental failure problems
Target Characteristics	
Velocity	Antenna scan time and angular tracking rates Permissible operator reaction time Pulse repetition rates
Number of targets	Antenna size for adequate angular resolution Pulse width for range resolution Area of scan required to encompass all targets Requirements for multiple radars
Target size	Basic parameters of the range equation

So few modulation techniques have been exploited in radar design because no real attempt has been made to efficiently utilize the frequency spectrum. The increasing problem of interference between the growing number of radiating devices may change this.

FM radars have been used primarily where only range information is desired and where only a single target is within the radar field of view. Radar altimetry represents a natural application of this technique but it is little used in missile radars except in a supplementary role as a range measuring device. Most continuous wave radars make use of the Doppler frequency shift principle and are known generally as Doppler radars. The major application for these systems is to derive a velocity input used with some form of dead reckoning guidance system.

The radar equation

The basic design tool for the radar designer is the radar range equation; for a single antenna it is:

$$R = \sqrt[4]{\frac{PA^2\sigma}{4\pi\,\lambda^2 NBKT}}$$

where

R = range at which signal to noise ratio equals one
P = transmitted power
A = antenna area
λ = operating wavelength
N = receiver noise figure
T = receiver bandwidth
B = Boltzman's constant
K = absolute temperature
σ = target cross section

This equation shows five independent variables under the direct control of the radar designer. Additional variables are introduced when the radar is modulated in any way to increase the information content of the received echo. Note, then, that there are many more than five possible variations in designing a radar for a specified range. Equation 1 provides no clue to the correct choice of modulation techniques, antenna beam shape, scanning or tracking techniques, or information readout. If an optimum design is to be achieved, the radar equation may be used as a design tool to check the design for range capability, but other design tools must be used to narrow down the possible choices.

The role of information theory

A second design tool available to the radar designer is the whole field of information theory concepts, which is only recently being adequately exploited in radar design. While information theory does not provide such a neat design equation as the basic radar equation, it does provide certain basic guides that assure optimum design of the radar system. It transcends the radar equation in establishing the limits of capability of various modulation techniques, and within the radar equation it assists in achieving minimum values for N and T. Information theory also allows a direct extension in range by providing techniques for operating at ranges greater than the arbitrary range stated in the radar equation.

The range equation was originally developed experimentally by equating the level of the reflected signal to the noise level through factors $NBKT$. Information theory, however, indicates that the limit of ability to separate the signal from the ambient noise level depends on the ability to make use of all information available that differentiates the signal from noise and to correlate this information with the observed characteristics of the received signal.

Actual applications of correlation techniques range from relatively simple filter designs up to techniques used in the reception of radar returns from distant planets where integration and correlation of signals may require years of study and computation involving massive computers to establish the presence of the signal within the noise background. Delay lines or other memory devices coupled with signal sampling by computers can afford signal to noise ratio improvements up to 20 db if computer complexity and computing times are unrestricted. For missile guidance applications, signal to noise improvements on the order of 6 to 10 db represent practical limits today depending on the complexity of the correlation.

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Doppler Radar Techniques for Aerospace Navigation

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The Doppler radar is a self-contained velocity sensor that can supply highly accurate data for long periods under all weather conditions. An extremely wide dynamic range of velocities may be measured from very low to very high altitudes. The velocity of the air vehicle is sensed by radar signals reflected from the earth's surface. Doppler ground velocity data is usually combined with a heading reference to compute continuous latitude and longitude.

General signal principles

The Doppler effect used by the radar velocity sensor provides a signal frequency proportional to the radial velocity of a radar reflector moving in the antenna beam. The Doppler equation is

$$f_d = \frac{2f}{c} V_r \tag{2}$$

where f = transmitter radio frequency
c = speed of light
V_r = radial velocity

The velocity measured by a radar antenna beam is the aircraft velocity component in the direction of the beam. Figure 13 shows a beam depression angle γ and an aircraft heading velocity V. In this case the Doppler frequency sensed is

$$f_d = \frac{2f}{c} V \cos \gamma \tag{3}$$

The antenna beam shown in Figure 13 has a composite receiver and transmitter antenna bandwidth, $\Delta\gamma$. The radar will receive a reflected signal which varies over the region of $\cos \gamma \pm \Delta\gamma/2$.

The Doppler ground return signal is, therefore, a spectrum of frequencies. The half-power width of the return signal spectrum is Δf_d. For small angles of antenna beamwidth

$$\Delta f_d = \frac{2f}{c}\left[\cos\left(\gamma + \frac{\Delta\gamma}{2}\right) - \cos\left(\gamma - \frac{\Delta\gamma}{2}\right)\right]$$

$$\Delta f_d = \frac{2f}{c} \sin \gamma \Delta\gamma \tag{4}$$

Figure 14 shows this frequency spectrum (Ref. 12). The ground (or sea) appears as a randomly distributed collection of signal scatters of varying reflectivity. The individual reflectors pass through the moving pattern of the aircraft's antenna beam, and

ANTENNA BEAMWIDTH CAUSES DOPPLER SPECTRUM

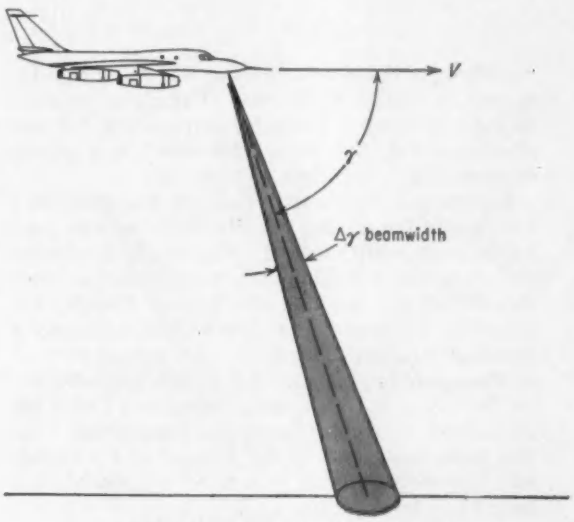


FIG. 13. Beam parameters in Doppler radar system.

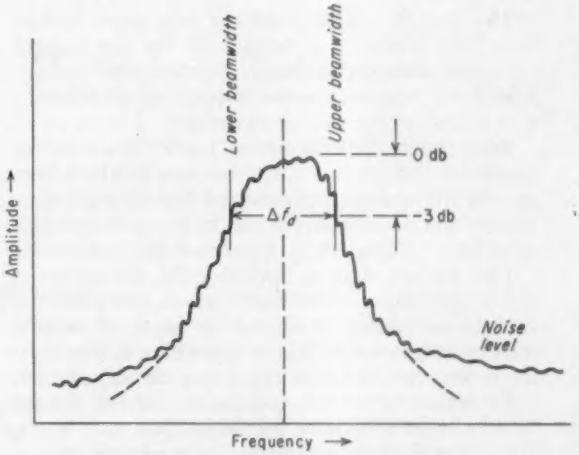


FIG. 14. Frequency spectrum of received Doppler signal due to finite beamwidth.

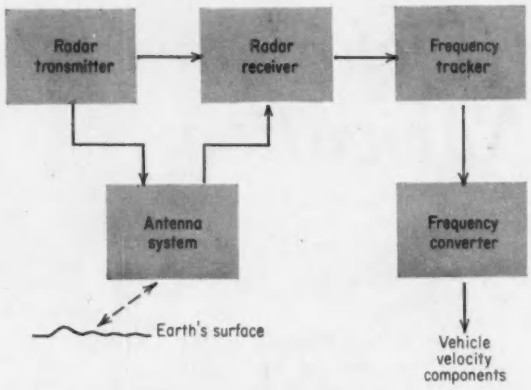


FIG. 15. Frequency tracker in typical Doppler system continuously determines center of Doppler spectrum.

the stronger signal reflections appear to change frequency as a function of time. Therefore, the short term Doppler signal fluctuates in frequency; but over a long period, the average frequency is a precise measure of velocity (Refs. 13 and 14).

Equation 3 shows that Doppler frequency is a function of the relative velocity of the aircraft radar beams to the earth's surface. The amplitude changes due to terrain reflections closer to or further from the aircraft do not alter the average Doppler frequency, are represented as symmetrical sidebands of signal modulation. Therefore, relative velocity is independent of terrain slope due to hills and valleys.

The International Telecommunications Union has established frequency bands for commercial Doppler radar navigation in the X band and K_e band, which cover frequencies from 8,750 to 8,850 Mc and from 13.25 to 13.4 kMc.

General system principles

Figure 15 shows the elements of a basic Doppler velocity radar.

The Doppler signal from the receiver is derived from the difference frequency of the transmitted signal and the signal received from the earth's surface. The center frequency of the Doppler signal spectrum is measured by the frequency tracker.

The output of the frequency tracker is a constant amplitude voltage of a single frequency, which is in general the average frequency of the received spectrum. (As occasional discrete targets pass through radar beamwidths, tracker frequency fluctuates.)

The tracker standardized Doppler frequency is fed to the frequency converter, which computes the data to an analog or digital function of vehicle velocity components. The computation is similar to the inverse cos γ (Figure 13); i.e., a sec γ multiplier.

To determine various components of the vehicle velocity, typical systems use more than one beam. For example, three beams can be used to compute the longitudinal, transverse, and vertical or normal velocity components of vehicle velocity.

Modulation

The performance of Doppler navigation radars depends primarily on transmitter modulation and receiver techniques. Commonly used transmitter-receivers are the continuous wave-coherent (CW-coho), frequency modulated continuous wave—coherent (FM/CW-coho), pulsed Doppler—coherent (pulse–coho), and pulse Doppler–noncoherent (pulse-noncoho) types. Table VII compares characteristics of the various types of systems.

Continuous wave systems have the simplest power supplies but require isolation between the receiver and transmitter. The transmitter-receiver leakage may be reduced by feedthrough nulling techniques. This allows CW Doppler radars to use the same antenna for transmitting and receiving on each beam (Ref. 15). Pulse modulated systems may time-share the receiver and transmitter, but the pulse rate must be controlled to avoid range holes at low altitudes which are caused when the return signals arrive at normal pulse transmission times. The pulse rate must be higher than the Doppler frequency received to avoid frequency and speed ambiguities, and the duty cycle must be kept high (on the order of 25 to 50 percent) to yield a good signal. Frequency modulated continuous wave (FM/CW) systems achieve a degree of transmitter-receiver isolation by using the time delayed characteristic of the ground reflected signal (Ref. 16).

The coherent receiver required in high duty cycle pulse systems demands isolation of the transmitter reference oscillator from the receiver as well as the normal main pulse isolation. Similarly the FM/CW system cannot tolerate transmitter leakage of noise sidebands to the receiver.

TABLE VII – CHARACTERISTICS OF DOPPLER NAVIGATIONAL SYSTEMS

Characteristics	Techniques			
	Pulse-noncoho	Pulse-coho	FM/CW-coho	CW-coho
Microwave circuits	Complex	Complex	Complex	Simple*
Modulation control	Complex	Complex	Complex	None
Increased fluctuation noise**	High	High	High	None
High altitude S/N	Inverse cube	Inverse square	Inverse square	Inverse square
Very low altitude	Limited	Limited	Good	Excellent
High velocity limit	prf	prf	No limit	No limit
Signal utilization	Less than 50%	Less than 50%	Less than 50%	100%
Antenna stabilization	Desired	Optional	Optional	Optional

Notes: *Separate transmitting and receiving antennas may be replaced by a common antenna with isolation techniques of moderate complexity.
**Velocity fluctuation due to altitude hole phenomena and to reconstitution of Doppler by integrating pulse data.

The simplest way to isolate the transmitter and receiver is to provide separate receiver and transmitter antennas. Some CW systems have been designed using two sets of antennas of three beam forming elements each.

Antenna configurations

Longitudinal velocity and transverse velocity, which are required from the Doppler navigator, can be obtained with two antenna beams projecting to the ground as shown in Figure 16. However, the velocity error of a typical two-antenna system is very critical to errors in pitch angle measurement. The Janus configuration (a set of antenna beams which look both forward and backward) minimizes the effects of pitch angle errors and vertical velocity.

Figure 17 shows possible configurations of three-beam and four-beam antennas. The longitudinal and transverse velocities may be measured directly in Figure 17A. The three-beam lambda configuration can provide all three orthogonal aircraft velocities. The four-beam Janus system adds a degree of redundancy for checking and reliability. The antennas can be either fixed to the airframe or stabilized to earth or ground track coordinates. Noncoherent pulse systems require horizontally stabilized antennas to provide simultaneous arrival of signal from the forward and aft beams. Pitch and roll would otherwise change slant range and receive time. Ground track stabilization is also used to derive drift angle.

Antenna beams are fan shaped. Antennas may consist of phased arrays, parabolas, cut parabolas, and dielectric or metal plate lens systems. Linear and planar arrays can reduce the thickness of the antenna, but extreme beam angle stability for high accuracy systems is a state of the art problem.

Janus system beams may be sequentially switched to periodically sample each ground track. In this manner the full aperture of a planar array could be used for each beam successively. A current correlation-type system uses broad-beam antennas which are stabilized to the ground velocity vector (Ref. 17).

Receiver techniques

Early systems used a low prf pulse system, which compared the ground signals in a Janus system to obtain the difference in Doppler forward and backward. However, these early incoherent systems had very low time utilization efficiencies, and the high duty cycle systems have taken over. The Doppler receivers commonly used are both coherent and noncoherent to the transmitted signals. Noncoherent pulse-type radar receivers directly mix the fore and aft Janus antenna signals. The rf signals or heterodyned if signals may be mixed to provide the Doppler difference frequency signal.

Data processing

The Doppler signal is received as a noise spectrum of appreciable bandwidth, which is proportional to the combined receiving and transmitting antenna beamwidths. A 25-deg effective beamwidth at typical antenna beam angles gives a spectrum width of 10 percent of the Doppler frequency. The frequency converter combines the velocity information from the frequency trackers on each antenna to compute the longitudinal, transverse, and normal velocities in vehicle orthogonal coordinates. Analog voltages or digital data are the usual output.

In a system using fixed frame mounted antennas, the ground coordinate velocity data can be determined from the vehicle coordinate velocity data. The frequency converter output, directional sensors, and altitude sensors are used to compute ground velocity. A directional reference such as an inertially stabilized platform, gyrocompass, or a north-seeking device is used to determine the ground velocity vector. Vehicle pitch and roll attitudes effectively

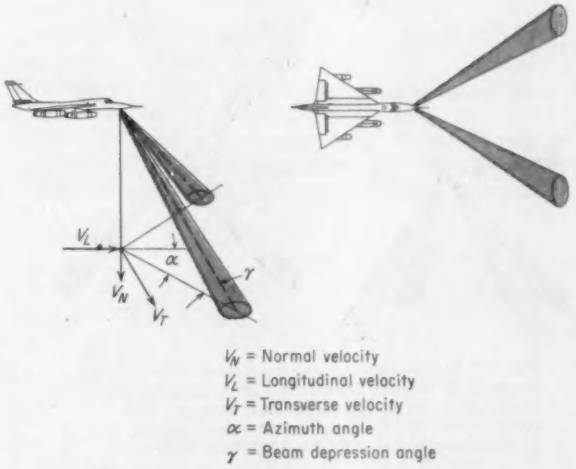


FIG. 16. Longitudinal and transverse velocity components can be calculated from the data received from two antennas.

tilt the velocity data in vehicle coordinates so that pitch and roll resolvers are utilized to rotate the data back to ground coordinates.

Vehicle velocity has been computed using cross-correlation techniques with broad beam antenna signals. Correlation provides a measure of the time for the vehicle to travel the distance of antenna separation on the vehicle (Ref. 17).

Accuracy

Many factors affect the accuracy and stability of Doppler radars. Transmitter frequency, signal fluctuation, data processing, antenna angles, and surface reflectivity effects are all sources of error. Some of the errors are directly due to system techniques and may be calibrated out, and others, although random, may contain systematic components.

• **Transmitter frequency**—The Doppler frequency is

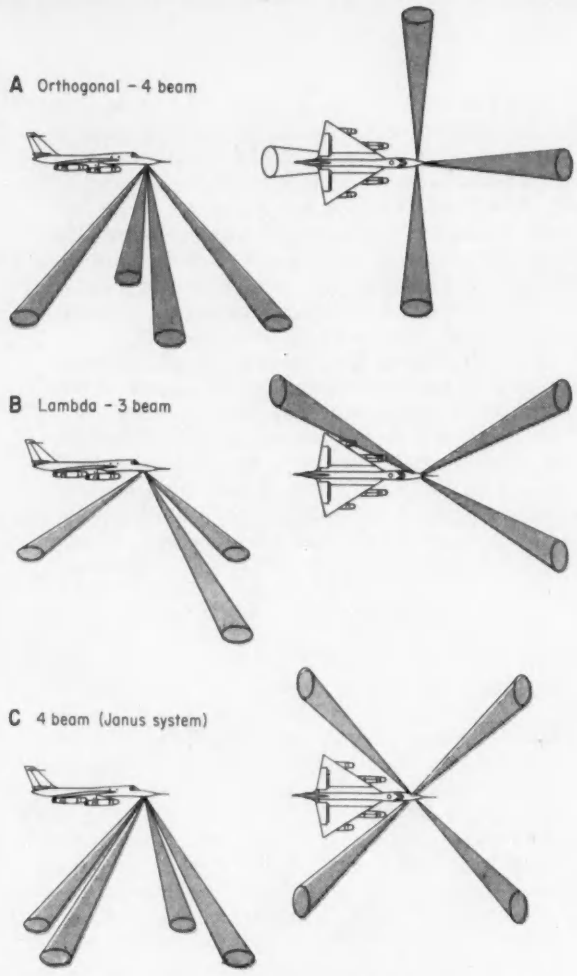


FIG. 17. A—Four-beam system can measure transverse and longitudinal velocities directly. B—Three-beam lambda configuration can provide longitudinal transverse, and vertical velocities. C—Janus system adds redundancy to lambda configuration for checking and reliability.

directly proportional to the frequency of the microwave transmitter. Therefore, the transmitter frequency must be held within the accuracy tolerance for the system. Very precise systems augment the transmitter tube stability with a frequency control loop. The AM and FM noise on the transmitter limits the system sensitivity and high altitude characteristics so that careful tube and power supply consideration are required for high performance.

• **Data processing errors**—The error in velocity measurement from the Doppler data can be traced through the data processing circuits to the ground coordinate data output. The frequency measurement by the tracker is fairly precise. Current discriminator-type trackers have errors of only 0.02 to 0.05 percent of the Doppler frequency.

The data from a stabilized antenna system are in ground coordinates, and are accurate to limits of the vertical reference and servo control tolerances. The stabilization computer that converts the vehicle Doppler data back through pitch and roll corrections also depends on the vertical reference tolerance. The currently used analog voltage-type computation with resolvers may be further refined by digital computation of pitch and roll correction. Over rough terrain, it is considered easier and more precise to stabilize data instead of the antennas. But signals from smooth seas and extreme vehicle attitude are better processed with the stabilized antenna.

• **Antenna angles**—The antenna beam angles must be very precisely boresighted for a highly accurate radar system. It is possible to align and install antennas with preset angles so that inflight calibration is not required. Systems of lower accuracy can adjust calibration from flight test data.

• **Surface reflectivity effects**—The reflectivity or radar backscattering coefficient from rough terrain does not vary appreciably with the looking angle. Therefore the signal level is constant over the antenna beam angle. However, the backscattering characteristic from smooth sea states seriously varies with the looking angle. At flat angles, ground clutter signals disappear on the radar over smooth seas. This results in the upper part of the beam having a smaller signal level than the lower portion of the beam. The shift in level reduces the Doppler spectrum center frequency; hence the measurement is low in velocity. This effect is commonly called "bias error" (Refs. 20 and 21). A degree of correction can be made by compensating for velocity error by a percentage increment upward, which is adjusted manually by a sea state switch.

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Modern Techniques in Celestial Navigation

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Celestial guidance utilizes the known orientations of all celestial bodies as a function of time and earth's position. For earth or near-earth navigation, the measurement of the orientation of two stars relative to the center of the earth is one way to determine position accurately. In this common technique the direction of the earth's vertical must be known and may be measured from a simple pendulum, an inertial platform, or a horizon tracker. The choice depends upon the application and, therefore, the operational characteristics of the vehicle, the accuracy required, and the degree of sophistication.

The equipment's telescope configuration may also take various forms depending on the vehicle's mission and related equipment. The use of an equatorial configuration (essentially the inverse of a planetarium projector) minimizes the need for computation. Sextants, astrocompasses, and single star devices usually employ a horizontal-axis arrangement with a gimbal suspension system which permits the altitude and azimuth of the star to be measured directly on the gimbal axis. Here, however, separate computations must be performed to translate these measurements into position and direction on the earth's surface.

Automatic celestial navigation

While the stars have been basic navigational aids for centuries, the advancement of electronics, photoelectronics, and system concepts gave birth shortly after World War II to automatic celestial navigation. One of the first demonstrations of this capability was made in 1947 by Kollsman Instrument Co. with a single star tracker at the U. S. Naval Observatory in Washington, D. C. In the conventional airborne application the star tracker significantly extends manual sextant capability by providing a way to correct present position in detecting the difference between computed star altitude and tracked star altitude. This difference, as shown in Figure 18, leads to intersecting "lines of position" which establish latitude and longitude when repeated on at least two celestial bodies. In addition, to determine precise aircraft heading the relative bearing angle of the star (to the aircraft) is simply added to the computed azimuth of the star.

Full navigational capability is assured when the heading and position capabilities described above are utilized in a self-contained airborne system. In conjunction with inertial systems, these provide:

- Rapid and precise ground or airborne azimuth alignment
- Subsequent monitoring of azimuth
- Means of correcting knowledge of present position
- Means of in-flight calibration of inertial system gyros.

In space vehicle applications the celestial tracker may take a number of specialized forms. One of these forms is the horizon scanner which simply tracks to the earth's center. In this form it can be used as the source of a geocentric vertical during injection, orbiting, and reentry phases. For attitude control of the space vehicle the sun sensor provides

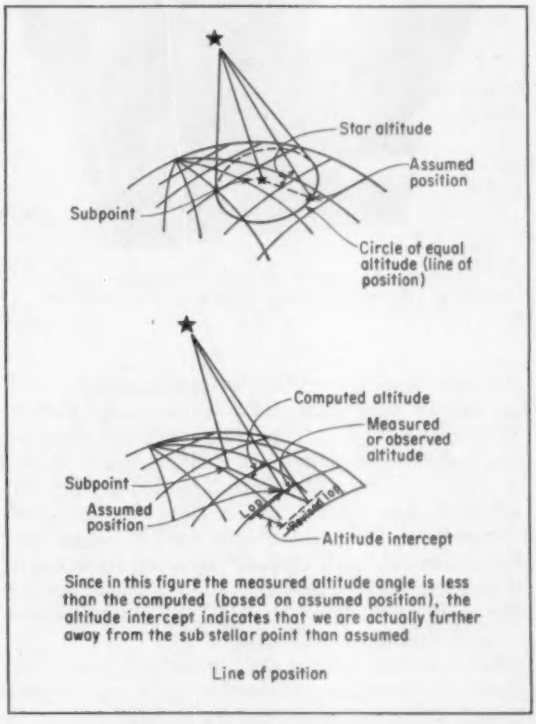


FIG. 18. Celestial navigation systems permit correction of position computed by dead reckoning techniques from previous known positions, as shown.

basic inputs for a heliocentric vertical. Additionally, star trackers can provide attitude stabilization relative to the inertial reference frame. For position determination the star trackers used in conjunction with the horizon scanner can provide accurate information for an orbiting vehicle, and in the case of the interplanetary mission, the sun, star, and planet trackers can supply the necessary position data.

• **Automatic celestial navigation**—Figure 19 shows an example of a completely self-contained equatorially mounted celestial system designed for the Navy as far back as 1948. This system featured a double modulation technique for automatic star acquisition and automatic gain control to compensate for stars and sky background of varying intensity. It also featured an array of telescopes and determined position and heading precisely by simultaneously tracking two or more stars and a self-contained vertical. This system's gimbals provided a direct measurement of latitude, longitude, and heading. A pool of fluid with desirable viscosity and damping characteristics was tracked photoelectrically to provide the vertical. This optical-link vertical system used Schuler tuning with airspeed damping to minimize the effects of vehicle acceleration. Flight tests of this equipment demonstrated high order precision in both position and heading.

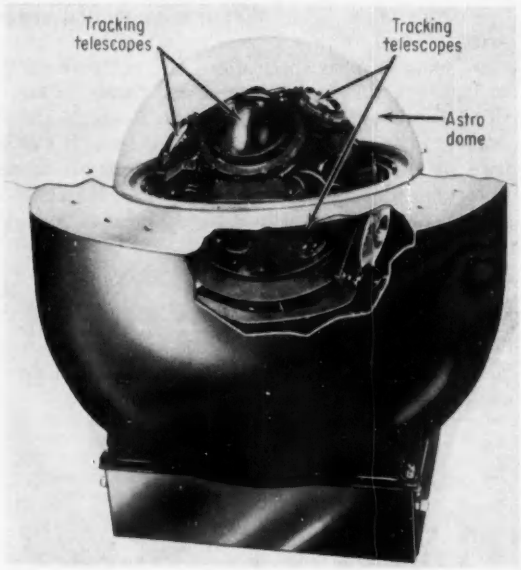


FIG. 19. Automatic celestial navigator uses double modulation technique, can track two or more stars simultaneously.

• **Stellar inertial systems**—In the exploration of other celestial techniques considerable effort was directed toward stellar-inertial navigators as employed in the Snark and Navaho missiles. Here the star trackers were physically integrated into inertial systems and provided stellar monitoring and supervision of the inertial system. Both the equatorial and the horizon-axis configuration were utilized in these programs. Remarkable navigational accuracies were demonstrated in many flight test programs. Stellar inertial systems have been considered for the B-70 and for surface vessel navigation.

• **MD-1 automatic astrocompass**—The MD-1 automatic astrocompass measures the relative bearing of a star and automatically combines this with computed azimuth. The result is precise aircraft heading. The accuracy of this system is 6 min of arc (rms). The automatic astrotracker is firmly mounted against the aircraft's top section with a 2-in. radius dome protruding. The 6-lb tracking telescope shown in Figure 20 is mounted in a stabilized roll and pitch platform which uses a vertical gyro for the horizontal reference. The servocontrolled axes of the tracking telescope measure the relative bearing and the altitude of the celestial body being tracked. The need for spherical computation is satisfied by a miniaturized mechanical celestial analog computer accurate to within a few minutes of arc, Figure 21.

This celestial computer is a gimbal computer which accepts inputs of latitude, star declination, and star hour angle and accurately computes the elevation and azimuth of the star to be tracked. It recreates in miniature the celestial sphere shown in Figure 22 and determines the azimuth and altitude for the sun, planets, or stars from any position and any time.

Modulation technique for tracking

Tracking techniques are rather simple, reliable, and precise and usually employ a double modulation concept which is illustrated in Figure 23. The star image is modulated first by a raster to establish a carrier which exists only when the star is within the field of the telescope and then by a shutter which establishes the relative orientation of the star within the field on a phase basis. The second modulation exhibits an amplitude variation which is related to the star's displacement from the optic axis. The precision of this technique in the MD-1 system is about 10 sec of arc, and greater precision can be attained with longer focal lengths and larger apertures. In many of the present applications, however, the basic factor limiting accuracy is the transducing and the transmission of this photoelectric accuracy. More advanced versions than the MD-1 have been developed for other applications.

New celestial technique

Almost without exception all airborne celestial tracking devices in existence today are limited in their field of view or speed of response or both. These disadvantages can sometimes be turned to advantage. For example, ambiguous stars can be eliminated, noise which would prevent star detection reduced, and disturbances which would degrade system accuracy avoided.

Conventional systems employ a field of view of

AUTOMATIC ASTROCOMPASS

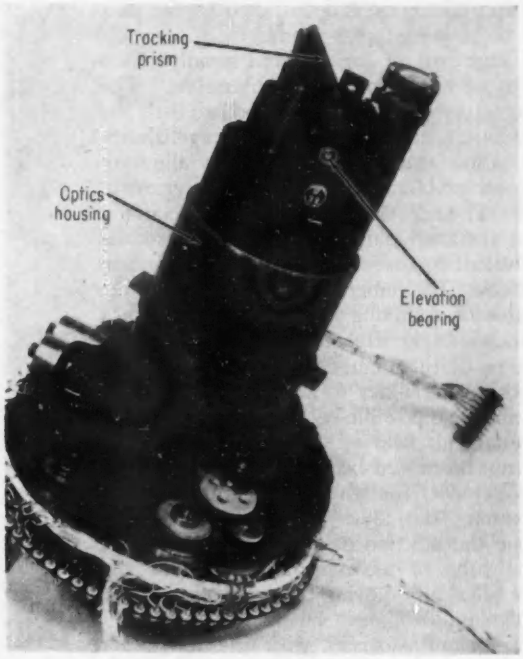


FIG. 20. Six-pound tracking telescope of MD-1 automatic astrocompass is stabilized by vertical gyro.

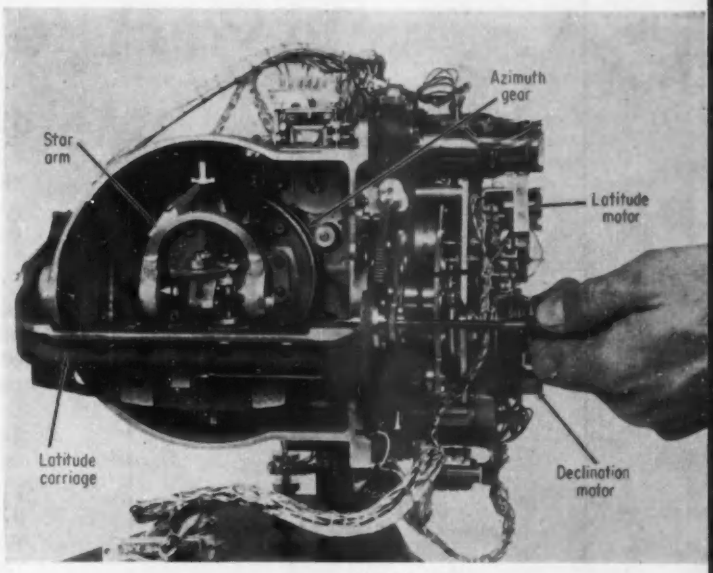


FIG. 21. Astrocompass uses mechanical analog computer which is minature of celestial sphere shown in Figure 22.

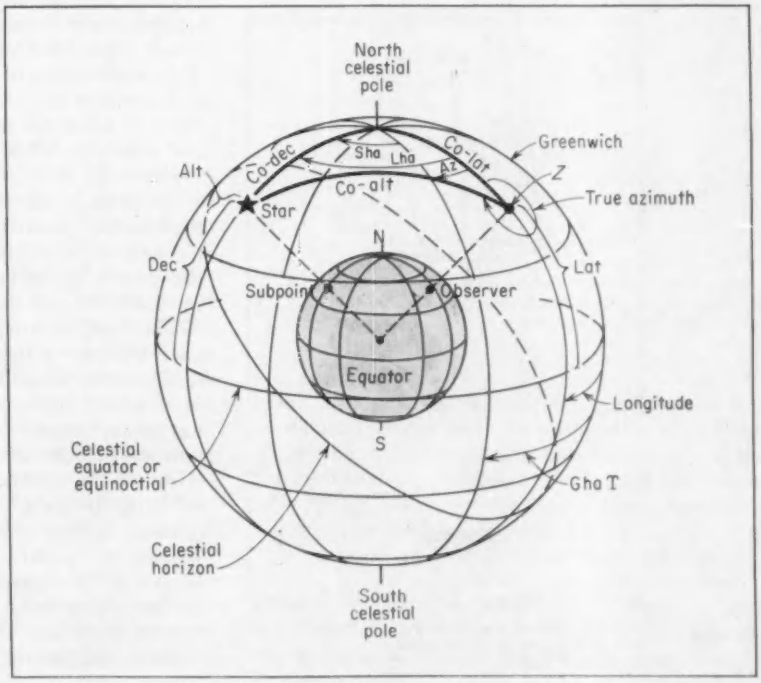


FIG. 22. The relative motions within this celestial sphere are imitated in the computer of Figure 21 to compute altitude and azimuth of star being tracked.

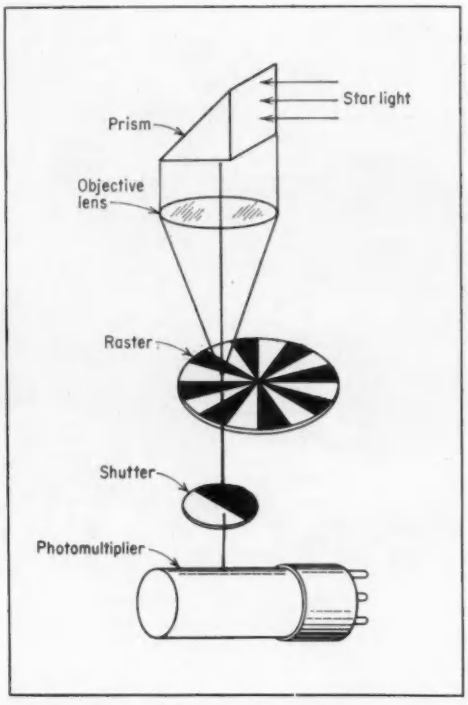


FIG. 23. Optical scheme of double modulation system used in automatic celestial navigator and automatic astrocompass.

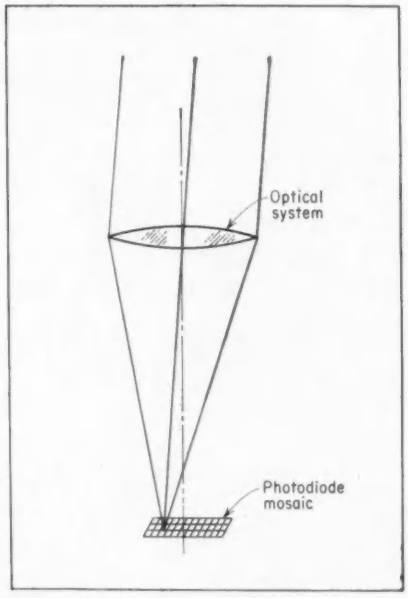


FIG. 24. Optical basis of solid state detector under development for celestial tracking.

one degree, at most, and as small as a few seconds, and they obtain celestial information by automatically aligning the optical axis of the telescope to the line of sight to the star. The speed at which the alignment can take place is determined by the parameters of the servosystem. An ideal device would observe a large part of the sky and rapidly follow the motions of several of the brighter stars. This ideal instrument would need no servoed gimbals and would thus have faster response and better reliability.

Discrimination against background sky illumination is a major problem in the case of the terrestrial star tracker. The scattering of sunlight in the atmosphere produces illumination in one square second of arc equivalent to that of the weaker navigational stars. Vidicon (TV camera tube) trackers promise to be capable of detecting a navigational star in a 2-deg solid angle of the daylight sky or a considerably larger portion of the night-time sky and also suggest star position accuracy to a few seconds of arc. This performance is possible because of the extremely small instantaneous field of view seen by the high speed electron beam and because of the integration of the starlight over the whole frame time. There also are scanning techniques which make it possible to determine the position of the star image on the face of the tube to seconds of arc without the necessity of physically moving the telescope. Thus, very high dynamic responses can be obtained.

A major problem associated with celestial tracker design in orbiting or interplanetary applications is the maintenance of performance over long periods. Solid state detectors are possible which provide the speed of television tubes but are much smaller, simpler, and far more reliable. Some solid state sensors under development promise basic sensitivity which approaches that of the best photomultipliers. The combination of these small detectors in mosaics and arrays is also being pursued to provide the features of a vidicon and yet preserve the compactness and reliability of the solid state elements.

Figure 24 illustrates schematically the use of such a device in a celestial tracker. The optical system focuses the parallel light from the star onto one element of the mosaic. Examination of each cell and the processing of intelligence is then accomplished by electronic and digital techniques.

The basic techniques of automatic celestial guidance are also progressing and are suggesting new navigational procedures. For example, in applications where traffic may be of no concern, celestial navigation permits the abandonment of the present position determination. One can navigate purely in terms of the celestial references and time, without reducing the data to an earth position. Flying the celestial sphere, flying toward a setting star, or arriving at a star's substellar point are all word images of the suggested concept. These techniques are becoming most promising and suggest a great simplification and simultaneously an increased precision in the science of navigation.

Recognition in Perceptive Guidance Systems

CHARLES J. MUNDO, *Raytheon Co.*

A principal goal for the engineers of perceptive guidance systems (those in which guidance sensors in the vehicle observe the target) is to evolve mechanisms with abilities to rival or exceed a human observer in distinguishing targets. Some simple techniques have already been developed toward this end, and other exciting new researches may lead to machines that can even recognize targets in complex patterns such as terrain maps.

Present solutions

Most contemporary perceptive systems depend upon some monolithic character of a target as a signature to distinguish it from its background. When such a unique signature exists, an analog filter can usually be devised which will enhance the target relative to the background sufficiently that a threshold detector will give output signals only when the target is in view. In general such signatures are complex and the optimization of several signature parameters must be considered to distinguish the target from its background.

Five factors are common today in making up the signature of the target:

- Intensity
- Spectral return
- Relative geometry
- Motion of the target, and
- Polarization of the returned signal.

The intensity of a target relative to the background noise depends upon the amount of background viewed, so that if the field of view is decreased the signal to noise ratio of the target is enhanced as shown in Figure 25. As the field of view is decreased, the target is seen over a smaller percentage of the total area to be scanned. However in the region where it is seen, the signal to noise ratio is greatly enhanced. (The principle is the same with the telescope.) Hence the intensity enhancement is paid for at the expense of having the target in view a lesser percentage of time, or if the sensor's response time is fixed, scanning time is increased.

The difference in spectral characteristics of the target relative to its background can also be utilized to enhance its signal to noise ratio. For example the sky background has its maximum output in the blue region of the spectrum because of Rayleigh scattering, while aircraft engines have their peak spectral response in the infrared region. Hence a whole class of infrared sensitive photocells and semiconductors may be used (in conjunction with filters) to provide target enhancement for aircraft against sky background. However this is paid for in scanning speed because of the longer time constants of red sensitive detectors compared to the blue.

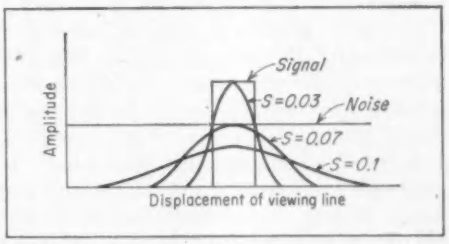


FIG. 25. Signal to noise ratio improves with increasing target resolution, s.

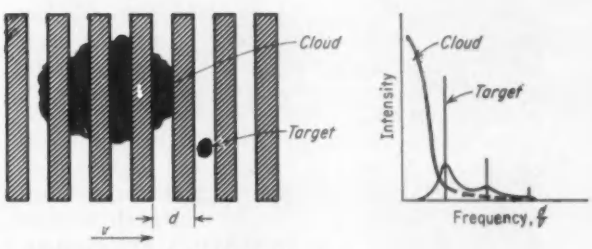


FIG. 26. Scanning with picket fence raster can enhance target signal at scanning frequency.

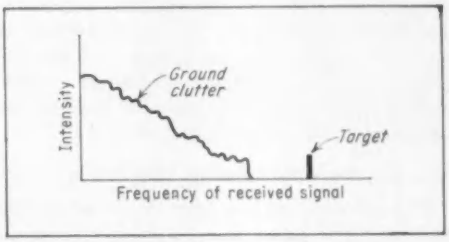
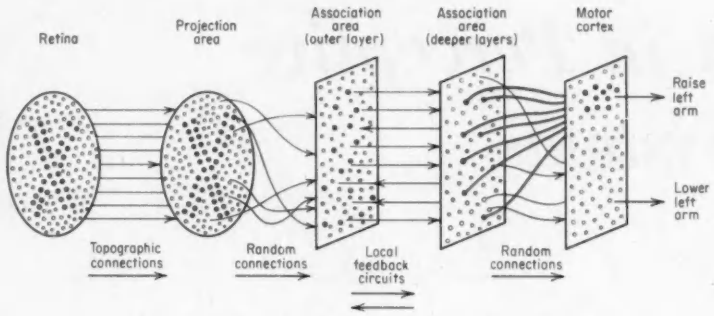


FIG. 27. Doppler shift due to moving target moves signal out of ground clutter from stationary objects.

An *a priori* knowledge about the size of a target relative to its background may also be realized to enhance the signal to noise ratio. Take for example an aircraft target against a cloudy sky background, where cloud areas have an integrated intensity far



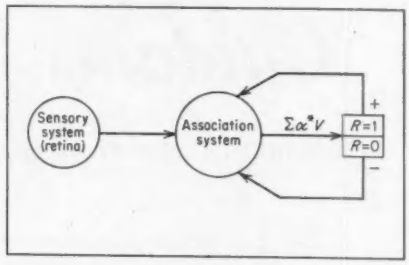


FIG. 28. A—Simplified model of organization of a human brain, see text. B—Simulation of brain's organization used in simple perceptron.

in excess of any targets. If a picket fence scanning raster with equal opaque and transmissive areas comparable in size to the target is moved across the field of view at a uniform velocity v, the target causes a signal equal to the half amplitude of its intensity $I/2$ at a frequency d/v. The large cloud background areas contribute a much smaller signal at this frequency proportional to the intensity at the edges or gradients in the cloud background, because the major part of the cloud covers several picket areas and the light is not interrupted when the scanning raster moves, Figure 26.

The velocity of a target relative to its background can also be utilized to enhance the target return. In radar systems the Doppler shift to the returned signal can be used to distinguish between a target and the ground clutter background. For example, the ground clutter seen by an airborne search radar is shifted in frequency by an amount proportional to the velocity of the aircraft and the sine of the declination angle. But a target that is moving toward the viewing aircraft also has an additional frequency shift proportional to its velocity. This shifts the target return out of the background clutter region so that a frequency filter can be used to isolate it from the ground clutter, Figure 27.

The future—simulating the brain

The recognition processes discussed to this point have all been based upon a fixed relationship that is preestablished between the target and its surrounding environment. This obviously requires that some class relationship exists that encompasses a sufficiently large set of targets-cum-environments to justify designing a specialized recognition system. In cases such as fixed ground installations, however, no large general class of such relationships exist. Yet with the aid of a very crude map a human observer can identify ground objects readily! Recent investigations have shown that machines can be built which possess this same cognitive ability. Although such machines cannot today take a complex map and use it to select a target, certain breakthroughs indicate that in the future such machines may provide one of our best guidance techniques.

Essentially, most of these machines are patterned after the randomly interconnected neuron networks of the human brain. Figure 28A shows a simplified model. The learning process is established by a positive stimulus for correct responses which weighs the transmission of signals through the neuron network to the motor cortex.

Computer programs have been developed at Raytheon, Bell Labs, and Cornell which closely simulate this brain model. In one set of experiments the capacity of a machine to self-learn the ability to distinguish between circles and squares was demonstrated to succeed 99.8 percent of the time when an association layer consisting of 500 associative units was exposed to the two patterns 1,000 times.

Cognitive machines must be based upon some type of learning algorithm. The simplest type of algorithm is one which reinforces the learned pattern when it correctly responds to the desired pattern and causes the pattern to deteriorate when it incorrectly responds. Such an algorithm can be instrumented as shown in Figure 28B by a three-layer machine consisting of sensory, associative, and response systems. The associative units are randomly interconnected in multiples with the sensory. The associative units give an output if the sum of the sensory inputs exceeds some threshold value. The magnitude of the output V_i from the ith associative unit depends upon the number of prior experiences of correct response and represents a stochastic variable. When the machine responds correctly, the active associative units have their value increased; and when the machine responds incorrectly, the associative units have their values decreased, with the further constraint that the sum of all values whether active or not is maintained at a constant. The units of the association system are simply connected to the outputs of the response system.

Experiments show that systems of this type can today build a simple recognition capability for geometric patterns when repeatedly exposed to them. In the future as research gives a better understanding of this learning process complex recognition problems involved in guidance will come into the realm of possibility.

What's Available in Europe for Electronic Process Control

European instrument manufacturers offer 13 electronic control systems which differ considerably in design and in input and output signals. A preceding part of this article (June 1960, pp. 103-107) considered equipment design and trends, tabulated information on all 13 systems, and described two systems. Five more electronic systems are detailed here. The remaining six will be reviewed in Part III of this special report.

DEREK BARLOW, Control Engineering
ERNEST D. MAY, London, England

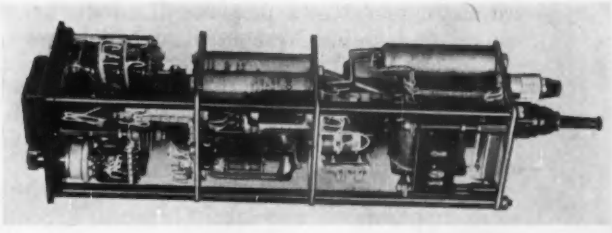




FIG. 1. Schoppe & Faeser controller.

Interest in European control systems is not limited to control engineers in Europe's widespread raw materials processing plants. To capture European markets for their products, many American companies are building chemical plants, refineries, and other complexes at selected locations in Great Britain and on the Continent. For economic reasons and to follow national-interest rules of the countries, American owned plants look first at European designed instruments to control their processes. Primary to the selection of control instruments is their design and functions. This report surveys these factors for European electronic process control systems.

Schoppe & Faeser GmbH, Germany

Schoppe & Faeser, a subsidiary of Hartmann & Braun, makes the smallest of the European electronic control systems: the panel cutout for the controller is only 96 x 96 mm and for the control unit, only 72 x 72 mm. Development began in 1947, with the first system installed in 1950 in a power station for boiler control. The system utilizes 0 to 12 vac input signal, with a controller output of 0 to 3 ma dc into 8,000 ohms. Although external resetting and cascading is possible, the controller only provides *P*, *P-I*, or *P-D* control actions. Under development is an amplifier to provide the rate characteristic for full three-term operation.

This electronic control system uses a differential transformer to convert absolute and differential pressure, level, density, and temperature into the 0 to 12 vac measured value signal. Two wires carry the transformer's energizing voltage from the controller, and two wires carry the measured value signal back to the controller, thus making a four-wire system. A mechanically operated local indicator on the transmitter provides on-site indication of the measured value, while optional fitting of a second differential transformer within the transformer housing gives a measured value signal for additional indicators and recorders. Transmitter accuracy claimed by S & F is 0.5 percent of FS with a resolution better than 0.02 percent.

The controller is made up of two basic modules: the control unit and the *P-I* or *P-D* amplifier. The control unit contains the setpoint knob which mechanically positions another differential transformer, an auto-manual switch, and the actuator re-

mote control adjustment. A twin movement meter displays the amplifier output current and the deviation between amplifier output and the manual control signal, thereby permitting bumpless automatic-manual transfer.

Figure 1 shows the front panel and internal construction of the Schoppe & Faeser controller. Error signal generation between the measured and desired values is achieved in a compensator circuit in the amplifier input stage. After amplification by the first of two tubes, the ac error signal is applied to a phase sensitive rectifier and then to a Miller integrator circuit to generate the time dependent control modes. Back coupling of the tube anode and grid circuits in the integrator—via a high value *RC* network with variable resistances—provides reset times of 0 to 2 min. Other circuit connections provide the *P-D* control mode. On the control panel a 13-position switch varies amplifier gain in exponential steps, providing a proportional band from 2 percent to infinity. In addition to built-in power stabilization for the Miller integrator, a magnetic voltage stabilizer provides a smoothed ac supply for up to 10 controllers. A four-position switch on the amplifier allows drift checks to be made on the dc integrator section.

The 0 to 3 ma dc controller output is applied to an electropneumatic converter (Hartmann & Braun TSD) to position the pneumatic valve actuator.

Hartmann & Braun AG., Germany

In the Hartmann & Braun UMC electronic control system, two wires carry the 0 to 20 ma dc measured value signal from the transmitter to the controller, and two other wires carry 220 volts at 50 cps to the transmitter from an external power source. The controller converts the transmitter signal to an output of minus 10 to plus 10 ma dc. This output signal feeds a power amplifier which in turn drives a three-phase asynchronous motor actuator.

Pressure, flow, and level force-balance transmitters convert the corresponding physical displacement into an electrical signal by imparting torque to a coil carrying beam. The coil moves in an electromagnetic field. The induced voltage feeds a magamp developing the 0 to 20 ma dc output. The magamp output signal is fed back to a pot-coil/permanent-magnet assembly at the other end of the beam, thereby balancing the beam. Replacing the pot magnet by electromagnets and adding auxiliary balance beams provides for differential pressure input flow conversion and for automatic temperature compensation of flow measurements. For temperature measurement with thermocouples, a transmitter converts 0 to 5 mv to the standard 0 to 20 ma dc measured value signal.

No local indication of the measured value is provided at the transmitter. Transmitter accuracies claimed by H & B vary from 0.2 to 1 percent depending on the variable being transmitted. All transmitters are housed in standard watertight cases; explosionproof cases are available.

The controller itself comprises three basic unit modules: the proportional unit and timing units generating reset and rate modes, Figure 2, and a constant-voltage power supply.

The proportional unit employs a magamp input stage followed by a tube amplifier stage to give an open-loop gain of 600. The input carries five electrically isolated primary windings. One winding injects the desired value signal, a dc voltage derived from a standard cell in the power supply. The other windings allow the algebraic sum of four signals from transmitter or controller outputs to be compared with the desired value, thereby permitting cascade operation, for instance.

Proportional band adjustment between 1.5 and 100 percent is achieved in 24 steps by a switched

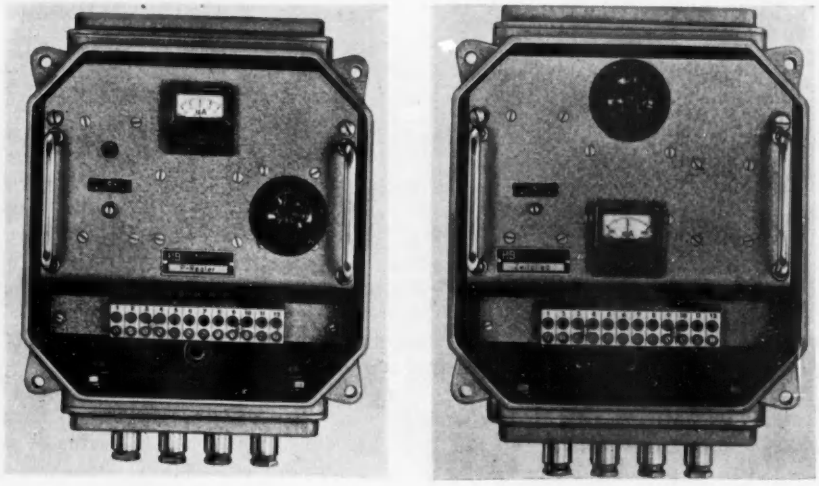


FIG. 2. Hartmann & Braun electrical control proportional unit, left, and function generating unit, right.

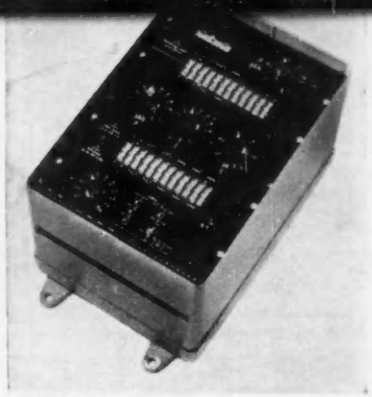


FIG. 3. Siemens & Halske remotely mounted controller features three functional units in one case.

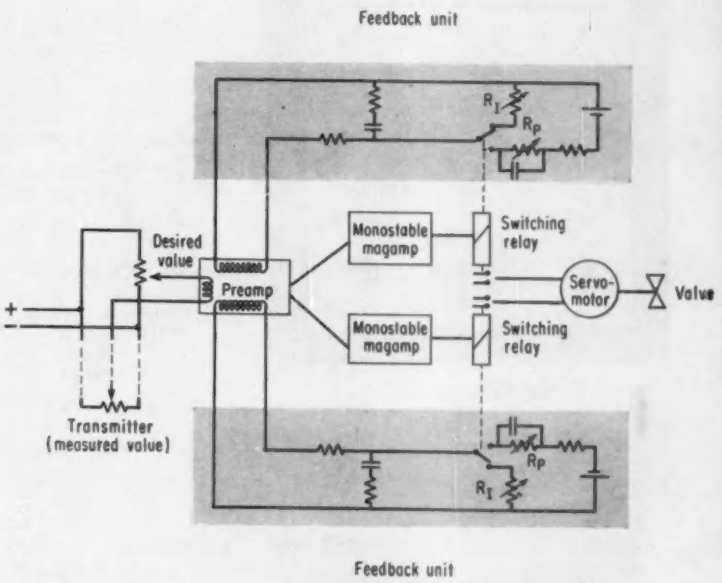


FIG. 4. Simplified circuit of Siemens & Halske Teleperm nonlinear controller.

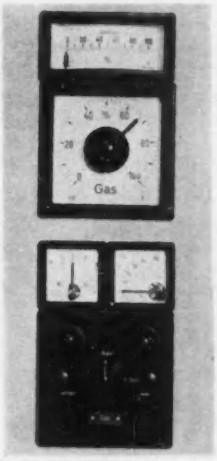


FIG. 5. Siemens & Halske's control panel.

current divider in the feedback loop from the amplifier output to one primary input winding. Series connecting the feedback winding to other primary windings increases the available proportional band to 300 percent.

For two and three-term control, reset and rate units are inserted in the feedback loop of the proportional amplifier. Each timing unit comprises a two-tube, unity gain amplifier with associated *RC* circuits. A 12-position switch adjusts the time constants between 0.05 and 20 min.

The minus 10 to plus 10 ma dc controller output feeds a power amplifier with 12, 50, or 100-watt, three-phase output to drive a servomotor actuator. Input signal direction determines the relationship of two phases in the magnetic amplifier output, thus controlling the direction of actuator travel. Actuator motors with a 30-sec response time, supplied by Brown Boveri, produce outputs from 12 to 100 kg-m.

Siemens & Halske AG., Germany

The Teleperm system is the first truly nonlinear control system marketed in Europe. (Teleperm is the electrical part of the Teleperm-Telepneu control system which features unit interchangeability, thus permitting any electric-pneumatic system ranging from a fully pneumatic Telepneu system to a fully electric Teleperm system.)

Teleperm employs a magamp controller with pulse duration and frequency modulation feedback of the output pulse varying with the magnitude of the deviation signal. The controller, Figure 3, contains three units for measurement, feedback, and control.

All measurement units provide error detection, but the actual type of unit employed depends on the associated transmitter. For flow and pressure, force-balance transmitters with individual built-in magnetic amplifiers operate from 220 volts, 50 cps. Diaphragm movement alters magamp input choke coil inductance. The resulting 0 to 50 ma dc output current flowing through a pot coil in a permanent magnet field generates the balancing force. Temperature transmitters for direct thermocouple connection use a gain stabilized magamp to give a 0 to 10 ma dc output.

Transmitter accuracy is better than 1 percent, and the response time is less than 0.2 sec. Temperature and pressure compensation for flow measurements can be obtained by adding a magamp and bridge circuit (in the transmitter) which operates additional pot coils in the restoring force electromagnet.

After amplification by an input magamp in the

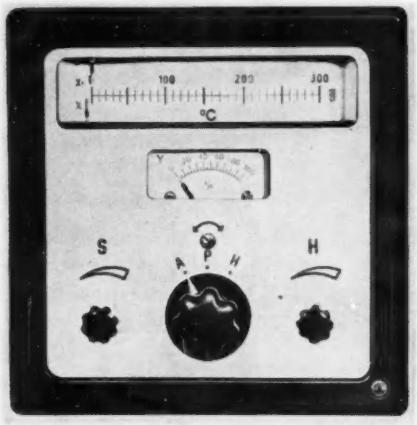
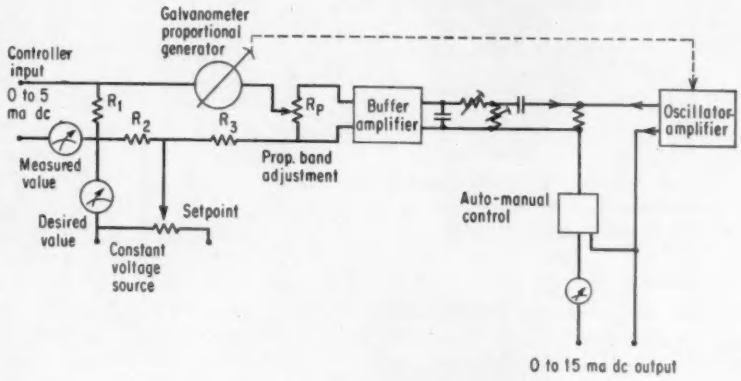


FIG. 6. The Joens controller for temperature loops.

FIG. 7. The Jones controller generates proportional action through galvanometer and rf oscillator arrangement.



control unit, Figure 4, the deviation signal operates two push-pull bistable magamps. Then output relays provide directional pulses to a servomotor actuator. Contacts on each relay bring in RC networks connected to the feedback winding on the input magamp. A deviation exceeding plus or minus 7.5 microamp switches in the network, causing a current buildup at the magamp input. The magnitude of this current is adjusted by a series resistance proportional band control. When the feedback signal nulls the deviation, the magamps switch off and the relay opens the feedback circuit. The feedback signal discharges through a variable resistance set to give an integral action up to 40 sec. After a preset time governed by the discharge rate, the bistable amplifiers again cut in to generate the next control pulse.

Pulse duration and pulse repetition frequency (prf) are both proportional to the deviation. Small deviations generate short pulses at a small prf. As the deviation increases, the pulse width and prf increase until at a certain deviation the relays are energized continuously. Minimum values of pulse duration are set at 220 microsec.

For processes requiring time constants greater than 40 sec., a plug-in thermal unit extends the feedback time up to 10 min. Temperature sensitive resistors detect the temperature of two metal bodies heated by outputs from the directional relays. A dc bridge comprising the resistors and the input magamp feedback winding develops a current proportional to the difference in temperature between the two bodies. Metallic U-links of copper and iron with different heat transfer rates provide time constants of 10,5, 2.5, or 1 min.

A range of squirrel cage motor-driven electric actuators is available for damper or valve operation. Actuator response time is about 30 sec.

Miniature (144 x 144 mm) panel mounted controls, indicators, and recorders are available, the controller itself being located away from the instrument panel. Standard front panel configurations, Figure 5, include setpoint and measured value indicators, manual-auto control, and remote valve positioning. Indicators show deviation and valve position. Measured value is indicated on a horizontally arranged edgewise meter. Pushbuttons with associated supervisory lamps provide remote control valve operation.

The largest Teleperm installation among the many installed for power station and boiler control will be in the German-built steel mills at Rourkela, India.

W. H. Joens & Co. GmbH, Germany

Development of the Joens electronic controller started in 1957, with production models, Figure 6, now installed in chemical, petrochemical, and steel plants. At present the transducer range allows only for thermocouple or resistance bulb temperature measurements. Claimed accuracy is 0.2 percent.

Feature of the system is the generation of the proportional term through a galvanometer and rf oscillator. Normal measured value input to the controller is a 1 to 15 ma dc signal. A self-compensating preamplifier extends the usable input levels down to 0 to 5 mv dc.

Figure 7 shows the system arrangement. The measured value signal is developed across resistor R_1 and compared with a setpoint voltage generated from built-in stabilized dc source. Desired value setting is indicated on one portion of the moving coil meter. Resistance R_3 in series with the desired value input allows for resetting-signal injection. Also in series with the deviation signal circuit is a moving coil galvanometer with a pointer-mounted metal vane. The deviation signal deflects the vane between the pickup coils of the rf oscillator, and the resulting signal is rectified and amplified to give an output directly proportional to deviation.

Again RC networks provide rate and reset terms. Reset ranges are 0.25 to 25 min and 0.25 to infinity.

Rate action is adjustable between 0 and 5 min. A buffer amplifier reduces interaction between the time dependent networks and the error sensing circuit. A potentiometer in the input circuits adjusts the proportional band in two ranges from 0 to 100 or 0 to 1,000 percent. The controller output is a 0 to 15 ma dc signal to the actuator. This signal is applied to an electropneumatic converter to generate a standard 3 to 15 psi signal for pneumatic actuators. Electrical position relays are also available for positioning valves using capacitor-start or three-phase motors.

Measured and desired value signals are indicated on a double pointer front panel meter, and external recorders (144 x 144 mm cutout) are available. Front panel controls include desired value setting, actuator hand positioning, and auto-manual changeover. A side panel at the rear of the chassis contains the proportional, reset, and rate action setting knobs, their lack of easy access preventing inadvertent adjustment during process operation.

Allgemeine Elektricitats Gesellschaft, Germany

The AEG control system combines electrical and pneumatic techniques: a two or three-wire electrical input results in a 3 to 15 psi pneumatic output. Reset and rate time functions are separately generated pneumatically in a pneumatic-electric feedback unit. The controller has no provision for cascading or external resetting.

The system's method of error detection employs a swing coil arrangement in which the measured value signal is applied directly to a fast (3-sec response) meter movement. Various meter movement sensitivities permit direct thermocouple measurements with minimum inputs of 15 mv and measurements from resistance thermometer bridges. For pressure, flow, and level measurements, two-coil inductive transmitters are used, the coils forming two arms of an ac bridge. Measured value indication is given from the meter movement by a horizontally arranged front panel pointer. The setpoint is adjusted mechanically by a pointer assembly carrying an electromagnet energized from the 50-cps supply. The outer limbs of the *E*-shaped magnet core are shaped inwards towards the center limb in an arc concentric with the measured value meter movement. A small gap is left at midpoint. Movement of the measured value pointer positions a small coupling coil along the curved arc of the transformer core. The coil output forms the error signal, with its amplitude and phase proportional to coil position with respect to the gap. At coincidence of the desired value and measured value, the coil is situated over the gap and zero error signal is induced.

Two single-tube amplifiers (in parallel to increase reliability) amplify the 0 to 100 mv ac deviation signal. Phase-sensitive rectifiers convert the amplified signal to a 0 to 10 ma dc signal to operate the plunger coil of an electropneumatic converter. Output of a force balance converter at 3 to 15 psi operates conventional pneumatic valve positioners.

The output is also returned via the pneumatic-electric feedback path to generate the three controller terms. Applied to a double bellows system, pressure variations actuate a pivoted beam to which is attached a coil operating in an ac magnetic field. Proportional control is obtained by varying the field excitation, giving a proportional band of 1 to 20 percent or 5 to 100 percent. An additional unit extends the proportional band to 300 percent. An adjustable restriction across both bellows provides a reset range of 0.1 to 60 min. A similar derivative range is obtained by a restriction in the input air

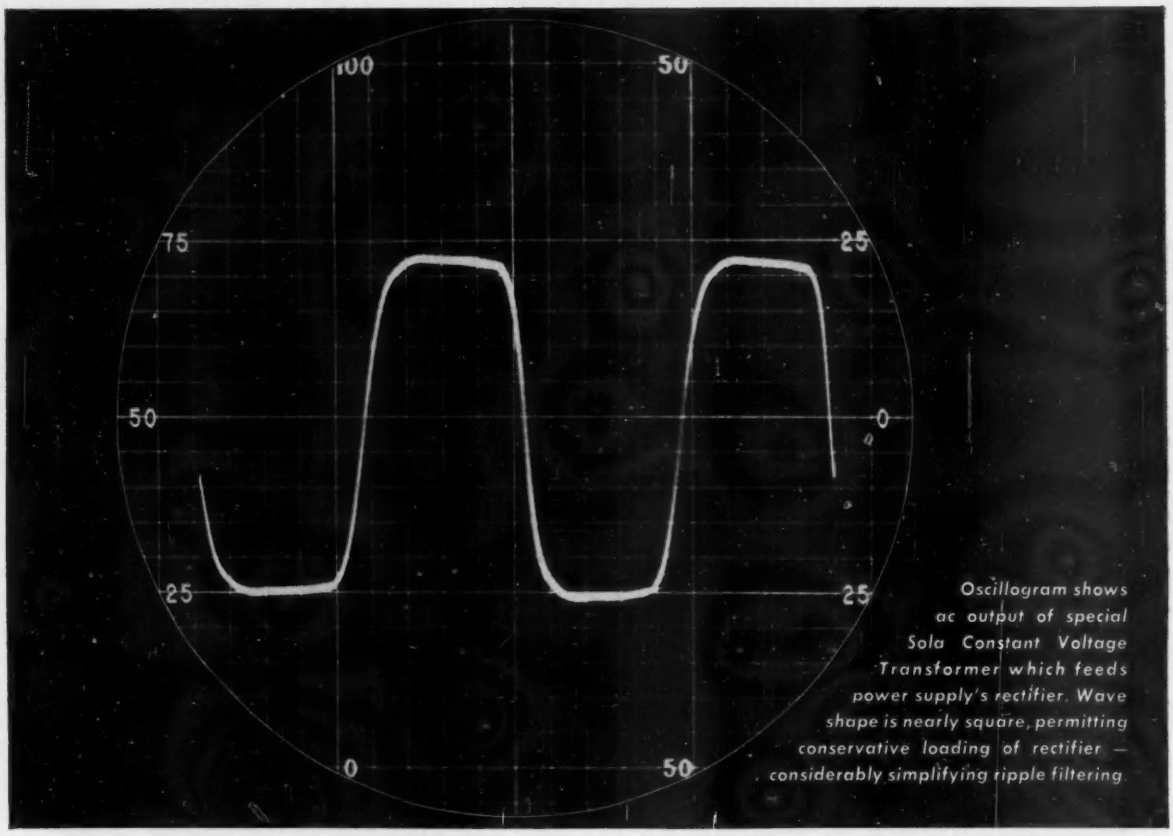


FIG. 8. The AEG electronic controller employs a pointer-mounted induction coil to develop the deviation signal.

supply. The rate and reset terms are fed back as an electrical output from the coil to the amplifier input to be summed with the error signal.

Figure 8 shows the controller housed in a 192 x 240 mm standard case. The controller comprises three subunits. The upper section is the twin channel amplifier (in later models it is transistorized). Pushbutton switches and a built-in meter allow amplifier current checks. Desired and measured values are indicated on the swing coil error detector unit, middle section. The lower section contains the pneumatic converters. A mechanical indicator shows the output deviation by registering the beam position of the pneumatic-electric converter.

The system has been installed for boiler control in electric generating plants.



Oscillogram shows ac output of special Sola Constant Voltage Transformer which feeds power supply's rectifier. Wave shape is nearly square, permitting conservative loading of rectifier — considerably simplifying ripple filtering.

Square-wave output of special transformer gives high efficiency in Sola's regulated dc power supply

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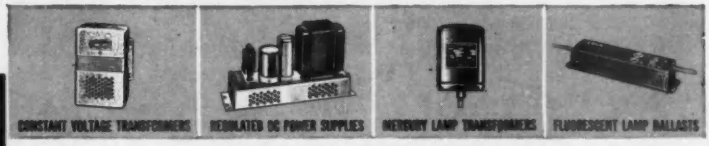
The rectified voltage feeds into the third component in this happy combination—the high-capacitance filter. The capacitor's filtering job is made easier because the rectified square wave contains a comparatively small amount of ripple. Final dc output from the filter has less than 1% rms ripple . . . for many applications there is no need for a voltage-dropping, efficiency-cutting choke coil.

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Making Sense Out of the Adaptive Principle

This is the first article in a three-part series on the Adaptive Principle. In Article 2 author Gibson will describe in detail several adaptive systems that have been built. In the final article he will discuss possible applications and the future of adaptive controls.

GIST: Is there such a thing as an adaptive control system? The author says there is and defines carefully what it is. He sees the adaptive principle as an extension of conventional control systems to overcome their limitations. The adaptive control reacts or adapts to its environment. It automatically measures the characteristics of its outputs and the process being controlled, and, on the basis of these measurements, adjusts the over-all system to optimum characteristics. Such an interpretation implies three criteria for the system: 1) there must be defined an optimum operating condition or figure of merit, 2) the system must compare actual performance with that desired, and 3) it must adjust the parameters of the system to drive the actual toward the desired.

In the past, when control system performance has been limited by changes in environment, designers have programmed variations in the control or used nonlinear systems. There are many applications where these approaches are unsatisfactory however, where the adaptive principle could be used to advantage.

The most important aspect of the adaptive system is the figure of merit against which the system measures its performance. Final response can be no better than this criterion. It can be a directly measured quantity, a calculated quantity, or a theoretical quantity. After a designer has selected a figure of merit, he must devise a method of measuring or calculating it. If the figure of merit is theoretical, he may cause the adaptive control to apply a step or some other test signal to the system and measure response directly, or he can cause it to calculate the response, without disturbing the system, by correlation techniques, using information from operating records. Finally, the designer has to evolve a technique to drive the system to the desired performance.

JOHN E. GIBSON
Purdue University

To some control engineers, adaptive control is the most exciting and promising new concept to appear in the field of automatic control in the past decade. With such a technique they envision ultimately the construction of man-like machines, capable of duplicating human action. But even the advocates have been unable to agree on what is an adaptive system. The principle of adaptive controls attempts to overcome those control system limitations brought about by changes in environment. It can be defined in this way:

An adaptive control system provides a means of continuously monitoring the system's performance in relation to a given figure of merit or optimum condition and a means of automatically modifying the system's parameters, by closed-loop action, to approach this optimum.

Such an interpretation consists of three items:

1. definition of an optimum operating condition or figure of merit.
2. comparison of *actual* performance with desired performance.
3. adjustment of the system parameters to correct the *actual* performance toward the desired.

Because of the first stipulation in this interpretation—definition of an optimum—semantic confu-

EXTREMUM CONTROL—
a subclass of
ADAPTIVE CONTROL

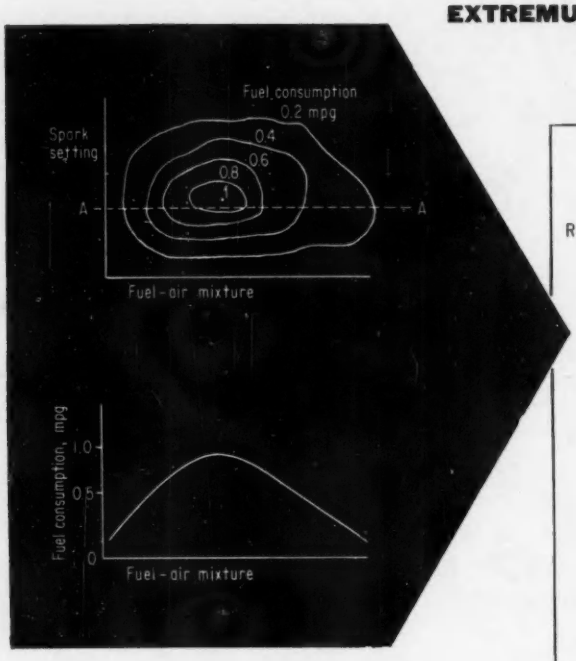


FIG. 1. Contours of constant index of performance for an internal combustion engine.

FIG. 2. Spark setting at value AA (Figure 1) produces a single dimensional adaptive control.

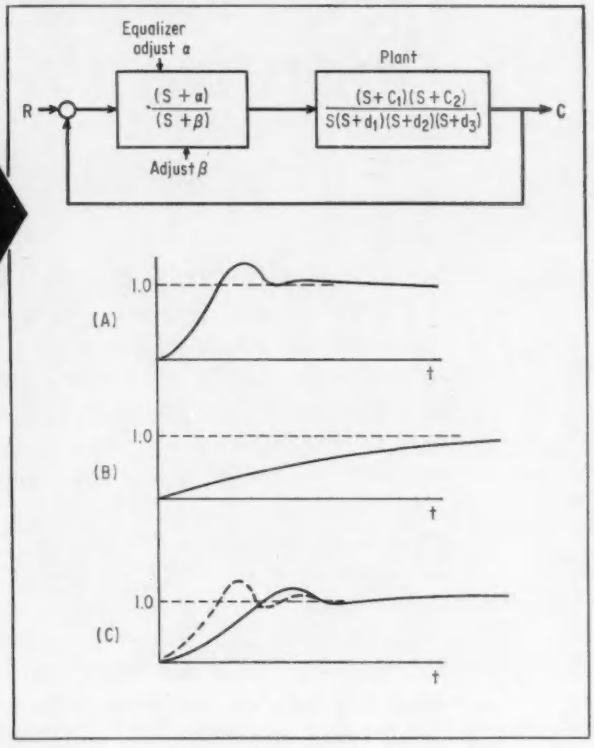


FIG. 3. Block diagram of a system to which an adaptive loop is to be applied. It could represent the dynamics of an aircraft.

FIG. 4. Step responses for aircraft.
A—optimum setting of α and β at sea level;
B—response of system at 50,000 ft.;
C—optimum setting of α and β at 50,000 ft.

sion has arisen between optimalizing (or optimizing or extremum) control and adaptive systems. It is the author's contention that an optimalizing control is a subclass of adaptive control. The extremum controller is a one dimensional adaptive control in which the index of performance (figure of merit) is directly measurable.

One of the keys to understanding adaptive systems is the index of performance or figure of merit and why it is necessary to introduce such a concept. The performance index is an objective means of judging the quality of a control system. In a conventional control system, rise time, bandwidth, static accuracy, etc. can judge the performance of the control and are considered performance indices. Usually, however, a performance index means a measure of the *over-all* performance of the system by one number. Obviously it is hazardous to characterize an entire system by a single number or parameter, yet this is what must be done in an adaptive system. Choosing the proper index of performance is an important decision in the design of an adaptive control system.

To clarify the concept of a performance index consider these two examples: the first, in which the I.P. (index of performance) is a quantity susceptible to direct physical interpretation and the second, in which the I.P. is a theoretical, contrived quantity.

First, in the extremum control for an internal combustion engine (Ref. 1), the I.P. is miles-per-gallon. In this system there are two controls (because of which this would be called two dimensional adaptive control) available to the operator: spark setting and fuel-air mixture. For various settings of these controls, different values for the miles-per-gallon calculation will be obtained. Figure 1 is a plot of such results. Constant values of mpg are connected with a line which is called a contour of constant performance index. Ideally, the adaptive loop will adjust the two to achieve the optimum.

In the simpler case of a single dimensional control, experience indicates that the spark setting A-A (Figure 1) is approximately the optimum value in spite of changes in environment and parameter variations. It is necessary only to adjust the fuel-air mixture. The cross section A-A in Figure 1 is reproduced in Figure 2. This simplification can be called an extremum control or optimizing control—

and indeed it is—but it is also a special case of the more general adaptive control.

All adaptive controls attempt to optimize some quantity, sometimes a physically interpretable quantity such as miles per gallon; other times a contrived value such as ITAE (integrated product of time and absolute error, described on page 117). ITAE is an index of performance based on the step function responses of the system (Ref. 2). In the block diagram of Figure 3, it is assumed that the plant cannot be modified by the control system designer. This might represent the dynamics of a given aircraft, for example, for which the designer must construct an autopilot. The equalizer is under the control of the designer who has to construct an adaptive loop to adjust the parameters α and β. A plot just like that in Figure 1 may be the result, but the I.P. is ITAE. Minimizing this integral will usually result in a very satisfactory step function response.

By properly adjusting α and β, the step function response of the aircraft at sea level in one axis is as shown in Figure 4A. But the parameters of the plant are quite different when the aircraft is at high altitudes: the optimum settings for α and β have changed. With the original settings constant, the response at the high altitude is seen in Figure 4B. When α and β are adjusted to their new optimum values, the response is as shown in Figure 4C. Although the response is optimized in Figure 4C, it is not quite as good as it was at sea level because of changes of the plant parameters.

In this example, optimum step response was a satisfactory criterion so that ITAE was useful as an I.P. Any number of criteria have been proposed for the quality of performance: RMS error, integral square error, IRAR, etc.—which are discussed on page 116. But at the start it is important to understand that any I.P. is an attempt to characterize over-all system performance by a single number and that such an attempt is essential to the concept of adaptive control.

The Background

Since there is a spirited difference of opinion about what constitutes an adaptive system, it is worthwhile to review what is behind the above definition.

A conventional negative feedback system is more tolerant of variations in loads and inputs (and sometimes internal parameters) than an equivalent open-loop system that attempts to perform the same function. As performance requirements stiffen and environmental specifications tighten, however, the high performance feedback system is no longer indifferent to variations. A large change in parameter values quickly degrades system performance beyond acceptable limits. In addition, a well designed linear system—which responds excellently to many types of inputs, including steps, ramps and sinusoids—will not continue to perform in an optimum manner if the input signal unexpectedly becomes heavily contaminated with noise, for example.

Nonlinear approach

Designers have attempted to cope with these problems in a variety of ways. Frequently they have experimented with nonlinear control systems. One such solution, for example, "programs" the deliberate adjustment of some system quantity, usually loop gain, to compensate for a change in parameters caused by a change in environment. The autopilot of a high performance aircraft is an example. Because the parameters of an aircraft vary widely as the plane climbs from sea level to 50,000 feet, the autopilot adjusts its loop gain as a function of altitude, thus compensating for the variations.

In another approach, the system is made to change its action radically as a function of the input signal or error. An example is the "dual-mode" servo. It acts as an optimum relay or "bang-bang" servo for large signals, but switches to a linear, proportional system for small errors (Ref. 3). An extreme example is the system of Taylor and Flugge-Lotz (Ref. 4); it switches between one of eight compensating networks depending on the character of the input.

Although these approaches can be classified as well designed *"adaptable" control systems*, none meets the definition given above of an *adaptive control system*. For one thing, all the corrective measures taken are open loop.

Possible applications of the adaptive concept

Problems that can be eased by the adaptive principle crop up in every field—in process control; machinery control; and aircraft, missile, and space vehicle control.

A useful application—one that prompted the original work in self-optimizing systems (Ref. 1)—is cruise control of the engine of long range aircraft. The problem: to adjust the controls of an internal combustion engine to obtain the maximum cruising

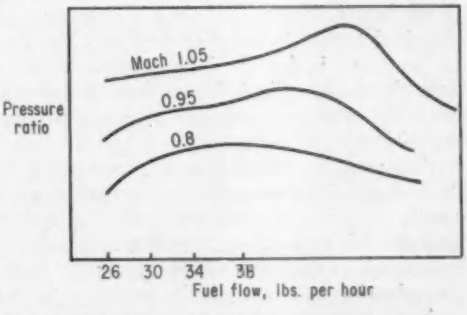


FIG. 5. To control maximum thrust per pound in aircraft jet engines, the control engineer works with the engine compressor ratio which is related to thrust. Figure shows a set of typical curves of pressure ratio vs fuel flow for different Mach numbers.

range per pound of fuel. Before automatic cruise control, such settings as throttle and fuel-air mixture were determined experimentally for each aircraft type by extensive tests on specific samples, and the results were tabulated in a "flight handbook". But even an extensive tabulation cannot cope with the changes in all the variables: air temperature, humidity, barometric pressure, individual engine variations, engine wear, and improper operator settings. And the calculation of the proper setting is so laborious that the flight engineer would perform it only every half hour. The automatic, continuously operating, cruise control has increased the cruising range of large four-engined aircraft by 10 to 20 percent in nonstop flights.

The usual procedure in automatic cruise control is to control manifold pressure ratio, which has been found to have a close relation to fuel consumption. Theoretically, the actual rate of miles per pound of fuel could be automatically calculated by an inertial navigation system, and then the rate could be a means to actuate the cruise control.

A slightly different problem to which the adaptive principle has been applied is the control of maximum thrust per pound in aircraft jet engines. Thrust is not available directly, but the engine compressor ratio is directly related to thrust. The usual procedure in applying the control is to maximize the engine compressor pressure ratio. Figure 5 is a typical set of curves of pressure ratio vs fuel flow. The curves, however, are not just a function of speed, as shown; temperature, humidity, and engine condition can vary them too. As a result, the peak cannot be obtained by simply programming throttle setting vs Mach number. Nevertheless, simple programming has been tried in jet fuel controls by mechanical three dimensional cams and nonlinear electrical resistors. But with cams or resistors, the solution is open loop and will not always be optimum.

Still another possible adaptive application is the case in which control system requirements conflict in the face of various possible signals. For example, when the input signal is uncontaminated with noise, the system response should be fast and crisp; but when the signal is imbedded in random perturbations, heavy filtering and sluggish response might be required to obtain superior results. The conclusion to be drawn is that the loop gain of the control system should be adjusted as a function of the signal to noise ratio for optimum response under various conditions (Ref. 5).

Applying the adaptive principle—causing a system to measure its own performance against a figure of merit or optimum condition and then to drive itself towards this goal—to such problems encloses hitherto open-loop operations within a closed loop. The nonadaptive system could be expected to deal with only those problems foreseen by the designer and provided for. The adaptive principle closes the loop since the adaptive system is capable of coping with changes and disturbances perhaps not anticipated.

The Figure of Merit

The most important aspect of the over-all performance is the figure of merit or performance index against which the system measures its performance. Final response of the control can be no better than this criterion. For some systems the figure of merit is a directly measurable quantity such as jet engine pressure ratio. In others, it may be a calculated quantity, which has direct physical significance, such as miles per gallon of fuel. In still other systems, the figure of merit is a theoretical one, a number that must be calculated and which, although related to system performance, is not of physical significance.

This third type of figure of merit, a contrived configuration, is the most difficult to handle.

The most exasperating characteristic of two such F.M.'s—the mean square error and integral square error—is unpredictability. The control engineer cannot be sure that the results have meaning in a particular design. The main justification for choosing them is mathematical tractability rather than intrinsic worth. Such criteria as figures of merit can lead to system designs that are unstable or physically unrealizeable. And worse, the results can be realizeable but erroneous. Even when the design is reasonable the results may not differ from designs made to simpler criteria such as phase margin.

An apparent improvement is the impulse response area ratio (IRAR) as a criterion (Ref. 6). It appears to qualify subjectively as a good criterion for second order systems because it yields a response that is desirable. In addition, IRAR can be used in a figure of merit that reduces to zero for proper settings of the optimizing parameter; it then becomes positive or negative depending on whether the parameter is too large or small. The simplicity of a null criterion in optimizing is a decided advantage.

The IRAR is defined as the negative of the ratio of the positive area of the impulse response of the system to the negative area. This ratio can be related to the damping ratio of the system, at least in the case of a second order system.

For a normalized second order system whose

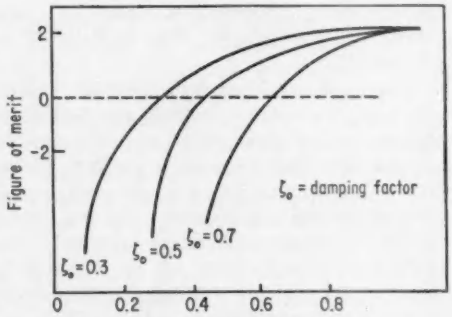


FIG. 6. If IRAR is used as criterion, the figure of merit can be defined so that it varies with ζ, the damping factor.

closed-loop transfer function is

$$\frac{C}{R} = \frac{\omega_n^2}{S^2 + 2\zeta\omega_n S + \omega_n^2} \quad (1)$$

The IRAR will be

$$-\frac{A_+}{A_-} e^{\frac{\pi\zeta}{\sqrt{1-\zeta^2}}} \quad (2)$$

a function only of the system damping ratio. If the figure of merit is defined

$$\text{F.M.} = A_+ + R_o A_- \quad (3)$$

where R_o is the value of IRAR for a particular damping factor ζ, the F.M. is of the null type. Figure 6 is a plot of the figure of merit defined by Equation 3 for various desired values of the damping factor. Although for higher order systems it would be impossible to write an equation such as Equation 2, relating IRAR to a simple function of damping factor alone, the IRAR criterion might still be used directly without the analytic development. Equation 3 remains as a definition whatever the order of the system. But IRAR has some serious limitations. A recent study (Ref. 7) which included some 14 various figures of merit showed that IRAR failed to yield a satisfactory response for higher order systems. This same study tentatively recommended the ITAE (integrated product of time and absolute error) of Graham and Lathrop (Ref. 8) for general use.

Measurement of the Figure of Merit

After a designer has selected a figure of merit for an adaptive system, the next step is to design a method of measuring it. For example, there are two ways to calculate the ITAE, which requires obtaining the error in response to a step function. One way is to apply the step to the system and measure the error directly. The second approach is to obtain the transfer function of the system by correlation techniques, using information from normal operating records and storing this in a computer. ITAE is obtained by driving the computer model.

The second, or indirect approach, offers several advantages. Most important, a disturbance required for direct calculation might be intolerable to the process. If the system was an automatic pilot for a high performance aircraft, the plane could go out of control while the test was being run. If the system was a chemical process, product could be spoiled by divergence from setpoint. Furthermore, removing the system from normal operation when the step is made would be a costly and time consuming procedure. Because the parameter values of the system are usually a function of the set point of the system, the disturbance itself changes the parameter values in trying to measure them.

Correlation techniques offer an answer. The cross correlation between the input and output depends on the system weighting function (Ref. 9):

$$\phi_{rc}(\tau) = \int_{-\infty}^{\infty} W(x)\,\phi_{rr}(\tau - x)\,dx \quad (4)$$

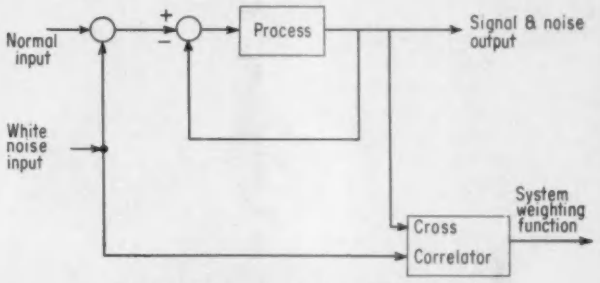


FIG. 7. Configuration for determining the system weighting function by cross correlation, an indirect method of measuring a theoretical figure of merit.

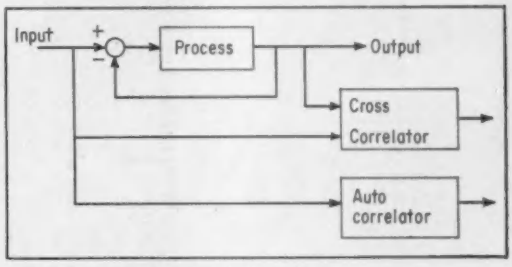


FIG. 8. Configuration for obtaining data to compute the system weighting function from normal operating data, without any special input.

where $\phi_{rc}(\tau)$ = The cross correlation between input and output
$W(x)$ = System weighting function
$\phi_{rr}(\tau - x)$ = Autocorrelation of the input

This relation parallels the convolution integral relation for system output

$$f_o(t) = \int_{-\infty}^{\infty} g(x)\,f_i(t - x)\,dx \quad (5)$$

so that ϕ_{rc} would be the system output if ϕ_{rr} were the input; if ϕ_{rr} were an impulse function, then ϕ_{rc} would be the impulse response. Because the autocorrelation function for white noise (noise with a flat frequency spectrum) is an impulse, calculating the cross correlation between it and the output supplies the impulse response of the system. Figure 7 shows a configuration for accomplishing this.

Using white noise is a compromise between direct and indirect measurement methods. Although adding white noise to the normal input does not incapacitate the system, especially for low intensity, it does not meet a nondisturbance requirement.

It is possible to do the same thing without any special input, although it may be desirable to operate in the frequency domain. Figure 8 illustrates a possible configuration. With this approach, the weighting function can be computed from Equation 4, or an equivalent spectral density relation can be derived from it for the frequency domain. A special purpose computer of relatively modest proportions can approximate the weighting function satisfactorily. In the system developed at Aeronutronic Div. of Ford

Motor Co., the weighting function is computed at 12 discrete points, and the area is approximated by the trapezoidal rule. The IRAR figure of merit then becomes the basis for adjusting the system for proper damping.

Driving the control to optimum

As the final criterion of the adaptive principle, the system adjusts to drive actual performance toward desired performance. Here are some examples of how this aspect has been carried out.

In jet engine operation, study indicates that for optimum engine setting, combustion-chamber pressure ratio should be at a peak. The optimum for such a system can be directly measured. The pressure ratio vs fuel flow curve has the shape indicated in Figure 9. It is necessary to determine the slope of the pressure ratio curve at the given operating point to determine whether to increase or decrease the fuel to move toward the optimum. Variation of the independent variable is required to obtain the slope. The small variations occurring in normal operation can be employed to generate this slope, and at least one system has been operated this way (Ref. 10). More frequently, however, a test signal or perturbation is introduced into the loop from an external generator. Optimization is obtained by introducing a controlled hunting or dither.

Simplest method of introducing the perturbation is to arrange a linear sweep of the independent variable (Ref. 11), as shown in Figure 10. Although the following is for single dimensional control, the principle is general. The relation between pressure ratio and fuel flow can be written as:

$$p_o + p = g\,(f_o + f) \tag{5}$$

Where p_o = optimum value of pressure ratio
f_o = optimum value of fuel flow

If it is assumed that the optimum varies slowly—constant, for approximate analysis—Equation 5 becomes, for perturbations near the optimum.

$$p = g\,(f) \tag{6}$$

Because the curve is a parabola near the peak, the equation for pressure ratio is

$$p = -K f^2 \tag{7}$$

Since f, as a function of time, has been assumed to be linear in segments, p vs time is parabolic in segments (Figure 11). And that means that the pressure ratio is a maximum only once in T seconds, so that there is an average difference between actual operation and the optimum. This difference is called "hunting loss" and may be calculated exactly as a function of Δ in Figure 7 or K in Equation 7.

The choice of Δ and T is one of engineering compromise. An increase in Δ makes more certain that the system will not lock onto a small local hump in the p curve rather than searching out the true maximum, yet it also increases the hunting loss. A decrease in T speeds up the response of the system, but it also increases the bandwidth requirements of the optimizing loop and can introduce components that interfere with normal input changes.

OPTIMIZING
JET ENGINE PERFORMANCE

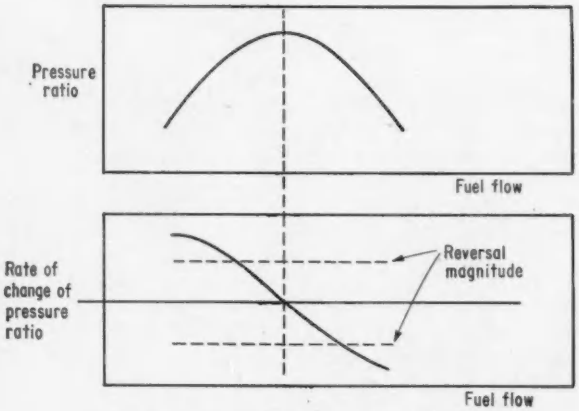


FIG. 9. To drive jet engine operation to a maximum, it is necessary to determine the slope of the pressure ratio curve at the operating point.

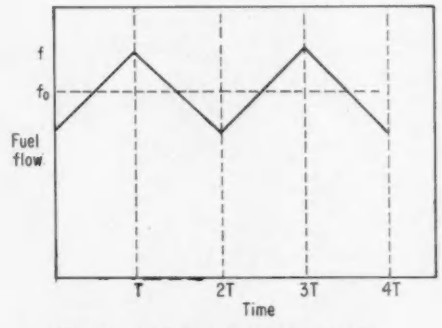


FIG. 10. Simplest method of introducing perturbation is to sweep linearly the independent variable, in this case, fluel flow.

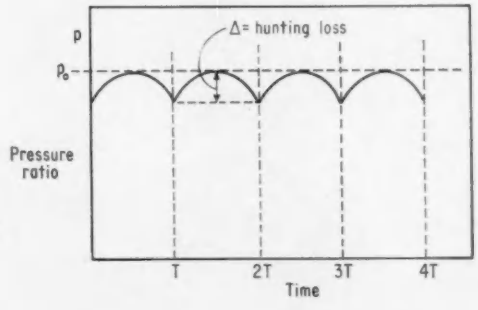


FIG. 11. Under linear sweep the pressure ratio can be assumed to be parabolic in segments.

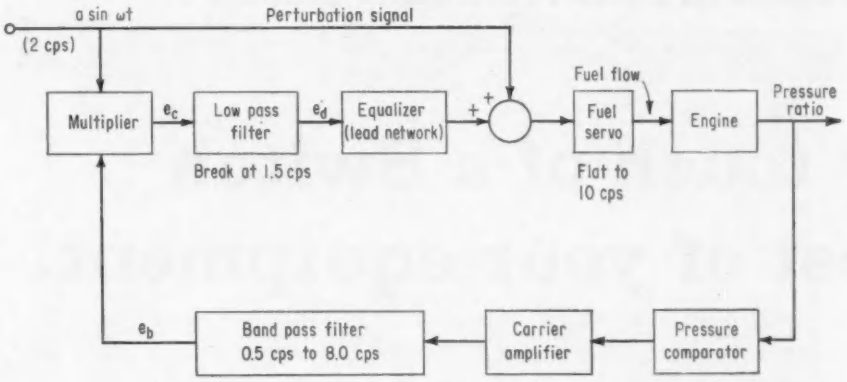


FIG. 12. Perturbing the jet fuel control system with a sinusoidal test signal.

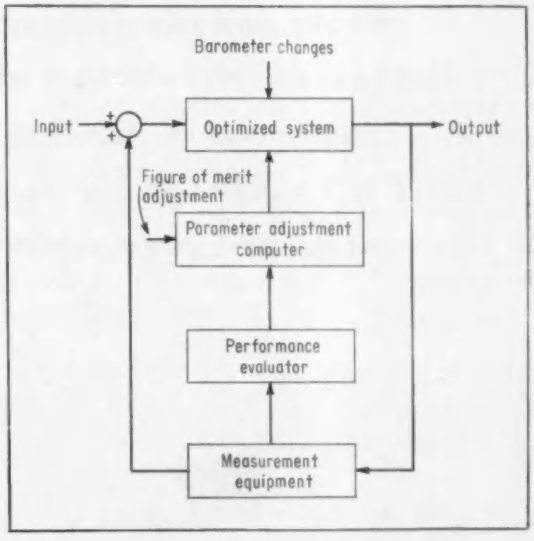


FIG. 13. Figure of merit is used for optimization in Aeronutronic adaptive control system.

The simple system described has at least one major drawback. It is necessary to differentiate p and use the magnitude of the dp/dt to trigger sweep drive reversal. Differentiation is not easy to do when noise is present in the system. For such conditions, the *peak holding system* method is preferable (Ref. 1). A voltage proportional to p is stored on a capacitor through a diode gate. As the value of p reaches a peak and then grows smaller, the peak voltage is held on the capacitor and compared to the voltage representing the actual value of p. When this difference reaches a predetermined value, drive reversal is triggered, the capacitor is discharged, and the process repeats.

A second simple method of perturbing the system introduces a sinusoidal test signal (Figure 12). If a parabolic relation near the optimum is assured, it is not difficult to show that the bandpass filter recovers the fundamental component of the pressure signal. Multiplication and low pass filtering then produce a dc signal proportional to the slope of the optimizing curve. The signal drives the system toward the peak of the curve (Ref. 12).

As a final example, a figure of merit rather than a quantity of direct physical significance can be used for optimization. A block diagram of the Aeronutronic system is shown in Figure 13. Measurement equipment generates a binary noise train that is superimposed on the normal input to the system. The noise is cross correlated with the output of the system and the weighting function of the system obtained in the same block. The impulse response area ratio (IRAR) is then calculated and compared to the desired IRAR in the block labelled "performance evaluator". The "parameter adjustment computer" consists of a servo-driven pot, which adjusts the gain constant of the basic system.

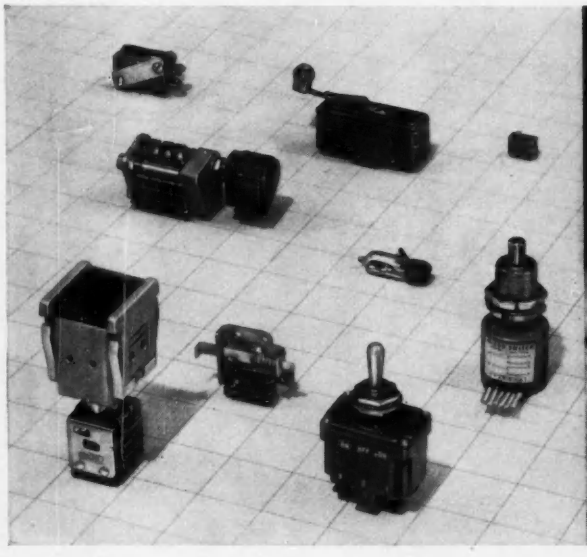
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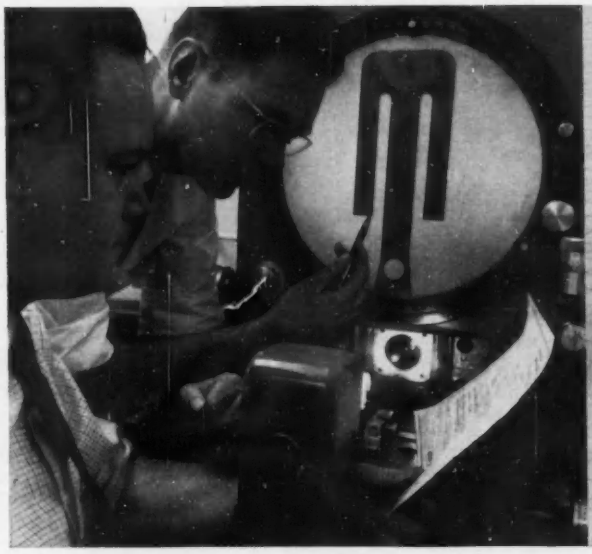
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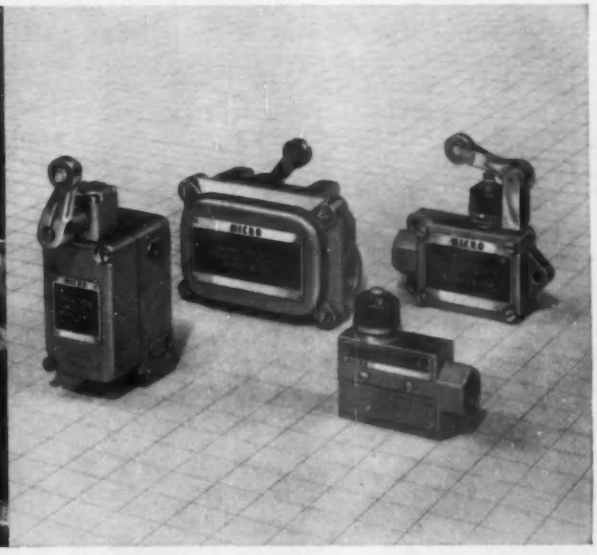
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GEORGE W. YOUNKIN
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Most numerical positioning systems use completely separate actuator systems for each direction of motion. The Giddings & Lewis Numeripoint control, however, employs a single constant speed motor to position both axes. Common equipment includes the motor and gear trains and control clutches for changing feed rate. Clutches on each axis connect the movable member to the common drive system and determine direction of motion.

Position information, consisting of seven digits and a sign for each axis, is entered through standard punched tape or manual selector switches. The sign is necessary since zero-offset adjustment makes it possible to place the origin at any point within the field of travel (Ref. 1). The least significant digit corresponds to tenths of thousandths of an inch; measured repeatability on a two-axis, 3-in. horizontal boring, drilling, and milling machine is plus or minus 0.0001 in., and absolute error is plus or minus 0.00015 in. Maximum traverse speed is 120 in. per min, decreasing in steps nearer programmed position.

Measuring position

The position transducing system uses a five-speed resolver network consisting of four conventional rotary resolvers and a linear Inductosyn. The conventional resolvers are connected by decade gear trains with one revolution of the lowest speed unit corresponding to 1,000 in. of travel and one revolution of the highest to 1 in. Fine positioning to a resolution of 0.0001 in. is accomplished with the Inductosyn; one cycle corresponding to 0.1 in. of travel is divided into 1,000 parts. The sine and cosine voltages required as position input information for the resolvers are derived from a digital to analog converter consisting of stepping switches and tapped precision transformers. Reference 2 describes the procedure for generating the necessary voltages from coded input information.

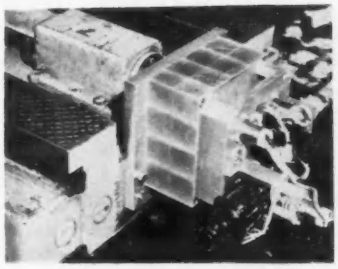
Control is switched from resolver to resolver as the programmed position is approached, switch points occurring when the angular position of the next higher resolution resolver corresponds to 90 deg from its electrical null. With a factor of 10 in resolution from one resolver to the next, switching occurs at about 9 deg from null for the lower speed (and lower resolution) resolver. This places the switching points at the following distances from the programmed position: coarse—25 in., coarse-fine—2.5 in., medium—0.25 in., and medium-fine—0.025 in. In addition, the Inductosyn fine data system has a switching point at 0.003 in. and a final one at the programmed position.

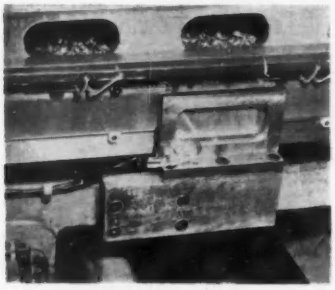
The synchronizing network for the five X-axis resolvers is shown in Figure 1 (the Y-axis network is identical). As control is switched from coarse to finer resolvers, a discriminator-switching system energizes relays XC through XFB in turn. The five switching relays are interconnected so that only one at a time can be energized. Their function is to set up combinations of control clutches, establishing the slowdown pattern. Direction control is achieved by thyratron-driven relays at the discriminator output.

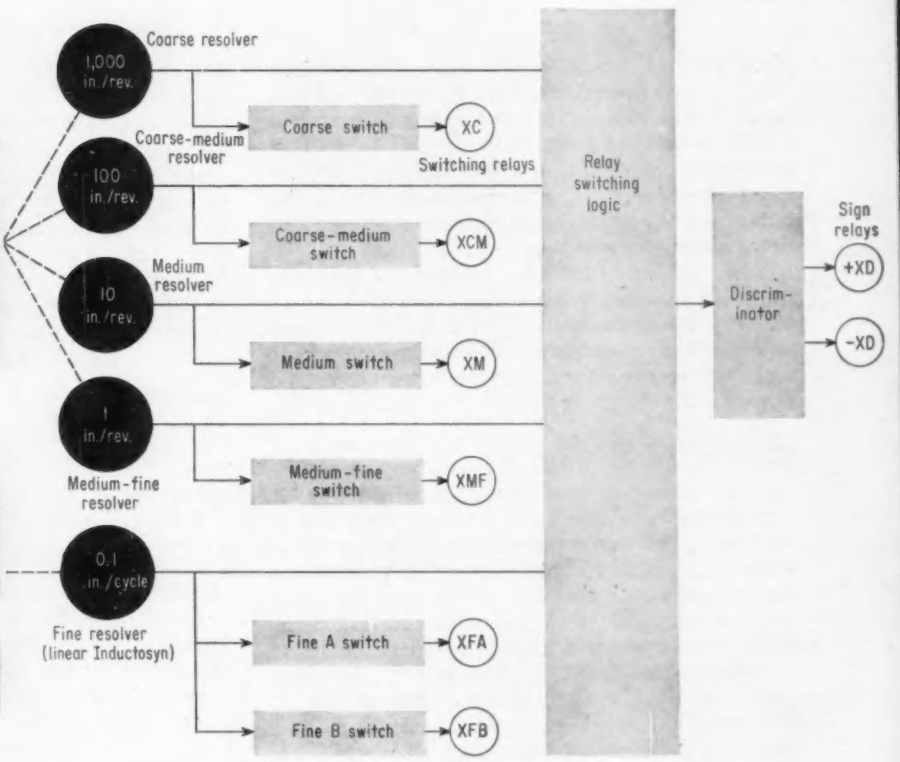
Establishing the slowdown pattern

The single constant speed motor drives an arrangement of gears and on-off clutches, different combinations of which can vary feed rate from 120 to 0.012 in. per min. Figure 2 lists the 32 different feed rates that can be achieved by energizing combinations

FIG. 1. Synchronizing circuit, rotary resolver package, and linear Inductosyn for X axis. Equipment for Y axis is identical.







FEED RATES AND SLOWDOWN PATTERN

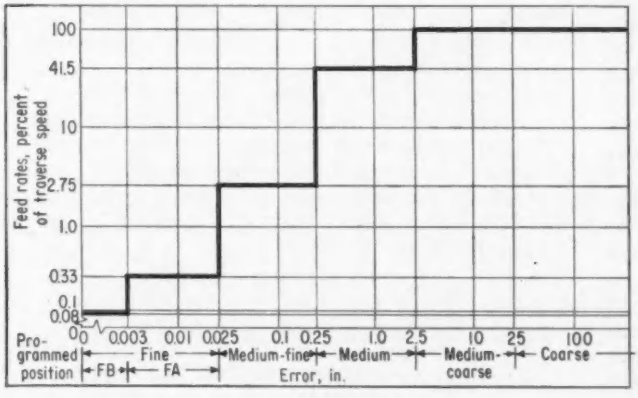


FIG. 3. Slowdown pattern in terms of feed rate vs distance from programmed position.

Feed No.	Feed Rate Clutches							Feed Rate, in./min.		
	H1	H2	H3	H4	H5	H6	H7			
1	X	X	X				X	120	Coarse - medium	Coarse
2	X		X				X	85		
3		X	X				X	65		
4			X				X	50	Medium	
5	X	X		X			X	35		
6	X			X			X	25		
7		X		X			X	20		
8				X			X	15		
9	X	X			X		X	10		
10	X				X		X	8		
11		X			X		X	6		
12					X		X	4.5		
13	X	X				X	X	3.3	Medium-fine	
14	X					X	X	2.5		
15		X				X	X	1.8		
16						X	X	1.3		
17	X	X	X					1.0		
18	X		X					0.75		
19		X	X					0.58		
20			X					0.42	Fine A	
21	X	X		X				0.3		
22	X			X				0.23		
23		X		X				0.18		
24				X				0.13		
25	X	X			X			0.1	Fine B	
26	X				X			0.07		
27		X			X			0.05		
28					X			0.04		
29	X	X				X		0.03		
30	X					X		0.02		
31		X				X		0.015		
32						X		0.012		

FIG. 2. Table of feed rates obtained by various clutch combinations. Only those rates directly under heavy lines are used in slowdown pattern of Figure 3; remainder gives variation of cutting speed.

of clutches *H*1 through *H*7. An optimum slowdown pattern is established for minimum positioning time based on decreasing speeds selected when control is switched from resolver to resolver. This is shown in Figure 3 in percent of maximum traverse speed vs distance to programmed position. The distance switching points are the same as those given above for resolver switching.

Note that only feed rates numbers 1, 4, 13, 20, and 25 (listed directly below heavy lines in Figure 2) are used during positioning. The other feed rates are available to give a wide variation of milling speeds for cutting service. Special control circuits to handle this situation are studied later.

Time-sharing the drive

With a single drive system as described here, it is not possible to have more than one feed rate at one time. This would create an impossible situation if the distances to the programmed position in the two axes were such that they fell in different speed ranges and two different feed rates were called for at the same time. For example, if the X-axis had a position error of 100 in., placing it in the coarse speed range and demanding a feed rate of 120 in. per min, while the Y-axis had an error of 0.1 in., placing it in the medium-fine range and demanding 3.3 in. per min, the control would be baffled.

A logical time-sharing network solves this problem by delaying motion in the axis with the smaller position error until the other axis enters the same speed range. At this time both axes are driven at the same correct speed, approaching the programmed position at 45 deg to the coordinate system. Axis delay while waiting for the other axis to enter the same data range is achieved by deenergizing the direction clutches on the delayed axis. Positioning continues until both axes are in the fine data range *FB* at which time each axis stops independently when it reaches the programmed position.

Two typical trajectories of the time-shared system are shown in Figure 4. The initial position for trajectory 1 lies in the medium-coarse range for both axes so that positioning starts by driving the machine member at a rate of 120 in. per min in both the X and Y directions. But because of the initially smaller error, the X axis reaches the medium speed range boundary before the Y axis does. At this instant the X-axis direction clutch is deenergized, and the X axis delays until the Y axis crosses the medium speed range boundary. From this point on both axes are driven together toward the programmed position, the feed rate in both axes decreasing simultaneously as the various speed range boundaries are passed. Trajectory 2 follows the same rules: since the X axis error is smaller in this case, the Y axis delays twice waiting for the X axis to catch up.

Two logical circuits are required to achieve this performance: one decides between motion or no motion of the two slides, and the other determines the feed rate. Both circuits use as input information the speed ranges in which the two axes are located, where axis location is indicated by the state of the switching relays in Figure 1. Thus the six speed ranges are designated *XC*, *XCM*, *XM*, *XMF*, *XFA*, and *XFB* in the X axis and similarly the Y axis.

If the two axes are in different speed ranges, the one closest to the programmed position must wait for the other to catch up; while if both axes are in the same speed range, they both must move together. These conditions are expressed by the following logical relationships:

$$\begin{aligned} X\text{-axis motion} = {} & XC + \overline{YC}\ XCM + \overline{YC}\ \overline{YCM}\ XM \\ & + \overline{YC}\ \overline{YCM}\ \overline{YM}\ XMF \\ & + \overline{YC}\ \overline{YCM}\ \overline{YM}\ \overline{YMF}\ XFA \\ & + \overline{YC}\ \overline{YCM}\ \overline{YM}\ \overline{YMF}\ \overline{YFA}\ XFB \end{aligned} \quad (1)$$

$$\begin{aligned} Y\text{-axis motion} = {} & YC + \overline{XC}\ YCM + \overline{XC}\ \overline{XCM}\ YM \\ & + \overline{XC}\ \overline{XCM}\ \overline{XM}\ YMF \\ & + \overline{XC}\ \overline{XCM}\ \overline{XM}\ \overline{XMF}\ YFA \\ & + \overline{XC}\ \overline{XCM}\ \overline{XM}\ \overline{XMF}\ \overline{XFA}\ YFB \end{aligned} \quad (2)$$

which are mechanized in the circuit of Figure 5.

To see how this works, consider trajectory 2 of Figure 4. Relays XCM and YM are energized corresponding to the location of the starting point. Under this condition none of the six OR terms of Equation 2 is satisfied so that there is no motion of the Y axis. The lower portion of Figure 5 agrees with this since the clutch circuit is open when the NC contact of XCM is open and the NO contact of only YM is closed. In contrast, the second OR term of Equation 1 is satisfied since YC is NOT energized AND XCM is. Thus the X axis will be driven in a direction depending on the state of the sign control relay XD.

When the X-axis error enters the medium speed range, XM is energized and XCM deenergized. Then the third OR terms of both Equations 1 and 2 are satisfied, and both axes move together until the Y-axis error enters the medium-fine speed range. Again none of the OR terms of Equation 2 is satisfied, and the Y axis delays until the X-axis error also enters the medium-fine speed range. Both axes then proceed to the programmed position together.

Related logical expressions can also be written for determining the correct feed rate depending on the error in the X and Y axes.

$$\text{Feed 1} = XC + YC + XCM + YCM \quad (3)$$

$$\text{Feed 2} = \overline{XC}\ \overline{YC}\ \overline{XCM}\ \overline{YCM}\ (XM + YM) \quad (4)$$

$$\text{Feed 3} = \overline{XC}\ \overline{YC}\ \overline{XCM}\ \overline{YCM}\ \overline{XM}\ \overline{YM} \times (XMF + YMF) \quad (5)$$

$$\text{Feed 4} = \overline{XC}\ \overline{YC}\ \overline{XCM}\ \overline{YCM}\ \overline{XM}\ \overline{YM}\ \overline{XMF}\ \overline{YMF} \times (XFA + YFA) \quad (6)$$

$$\text{Feed 5} = \overline{XC}\ \overline{YC}\ \overline{XCM}\ \overline{YCM}\ \overline{XM}\ \overline{YM}\ \overline{XMF}\ \overline{YMF} \times \overline{XFA}\ \overline{YFA}\ (XFB + YFB) \quad (7)$$

The circuit of Figure 6 mechanizes these equations. Note that even though one axis delays if it is in the coarse-medium range while the other axis is in the coarse range, the feed rate is the same for the two.

Consider again the initial position of trajectory 2 in Figure 4. With relays XCM and YM energized,

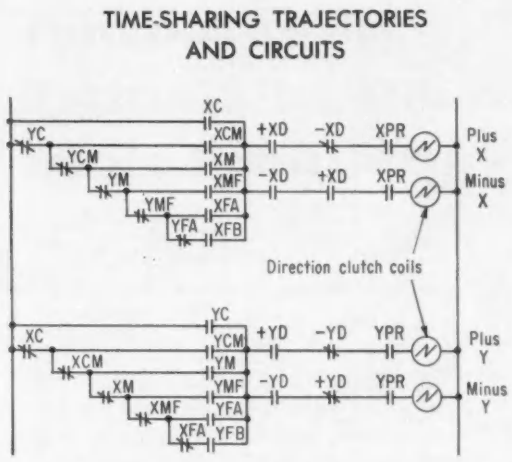


FIG. 5. Time-sharing circuit decides which axis moves and the direction of motion.

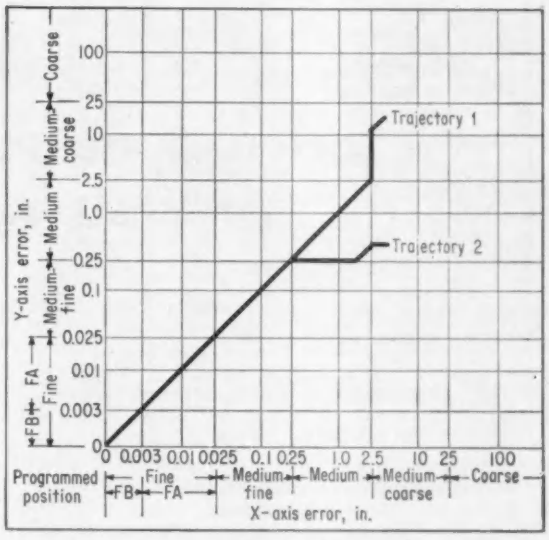


FIG. 4. Two typical positioning trajectories using single drive and time-sharing techniques.

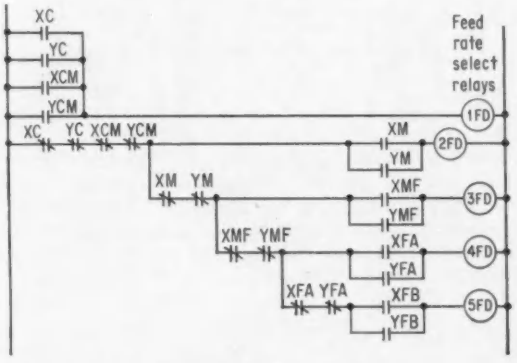


FIG. 6. Time-sharing circuit determines feed rate of common drive system.

Equation 3 applies since the *XCM OR* term is satisfied. The drive runs at feed rate 1. This follows from Figure 6 since with the NO contact of *XCM* closed and the NC contact of *XCM* open, feed rate select relay 1*FD* is energized. When the X-axis error enters the medium speed range, Equation 4 applies and relay 2*FD* is energized. Feed rate relays 1*FD* through 5*FD* select the proper control clutches through the slowdown matrix of Figure 8.

Positioning and stopping

The over-all positioning and stopping functions of the system are controlled from the circuit of Figure 7. When data readin for the next position is complete, relay *RIC* closes and the operator pushes the start button. With one of the switching relays (*XC* to *XFB* or *YC* to *YFB*) in each axis closed, relays *XSR* and *YSR* are closed, energizing positioning relays *XPR* and *YPR*. Contacts on the latter relays make operative the time-sharing motion circuit of Figure 5 and the slowdown matrix of Figure 8, and the system proceeds through its slowdown and positioning routine. Overlap is provided in the resolver synchronizing circuit so *XSR* and *YSR* remain energized as long as motion is required (for example, *XMF* closes before *XM* opens). When the *X* axis approaches its final position, *XFB* opens, *XSR* and *YPR* are deenergized, and the *X*-direction clutch opens to stop travel. The slowdown matrix of Figure 8 is kept energized through the parallel contacts of *XPR* and *YPR* until both axes have reached their programmed positions.

The switchoff points for the final relays *XFB* and *YFB* are set experimentally on the machine since stopping distance is a function of moving element inertia and clutch operating time. These vary from machine to machine, but it has been found that to stop within plus or minus 0.0002 in. it is necessary to set the *FB* relays to drop out from 0.0001 to 0.0003. in. before the machine element reaches position.

Controlling cutting speeds

During normal positioning operations the feed rate depends strictly on the distance to be traveled as dictated by the slowdown pattern of Figure 3. But if straight line metal cutting is being done instead of only positioning, the feed rate cannot be greater than the maximum allowable cutting speed, regardless of the distance to be traveled. On the other hand, it is still desirable to drive the machine tool member through the slowdown pattern once the distance to be traveled drops into the speed range where normal positioning speed is less than maximum cutting speed, since this pattern reduces total travel time. The slowdown and comparison circuit of Figure 8 accomplishes this by comparing the indicated feed rate with the maximum cutting speed and automatically selecting the lower of the two.

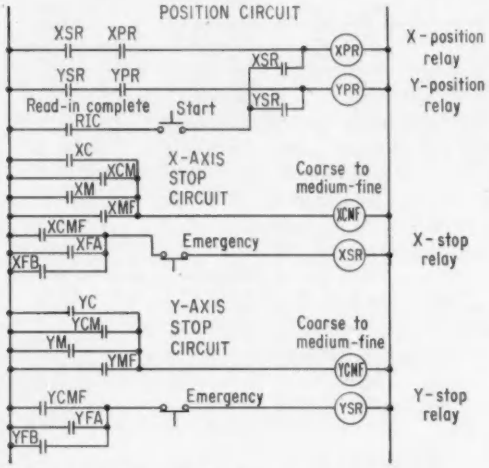


FIG. 7. Governing circuit for positioning and stopping functions.

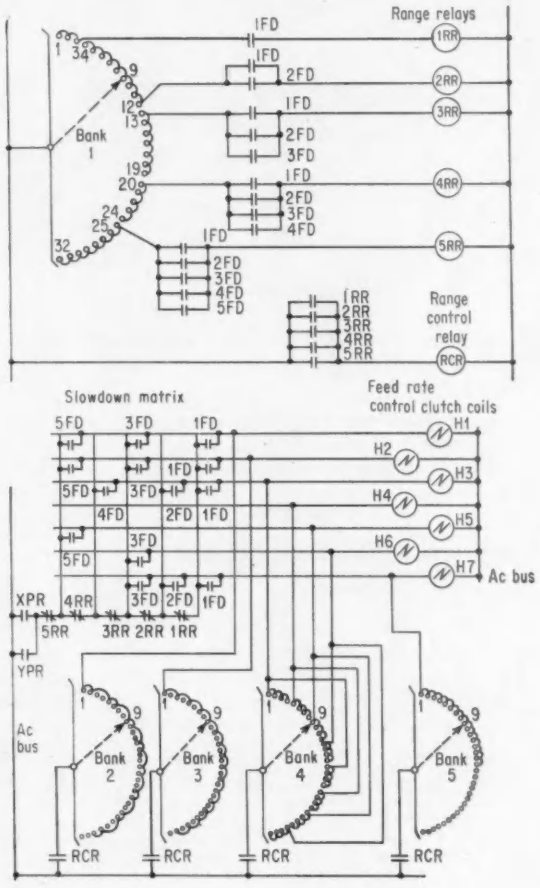


FIG. 8. Slowdown and comparison circuit controls clutch combinations at all times and limits feed rate during cutting operations.

The major components of this circuit are the slowdown matrix and the five-bank, 32-position plus home stepping switch. When the stepping switch is deenergized (in home position) the slowdown matrix operates in the manner described previously, energizing the control clutches in the proper combinations to follow the slowdown pattern of Figure 3. But when a cutting operation is being performed, the stepping switch intervenes to limit feed speed.

The switch is connected so that its 32 positions correspond to the 32 feed rates listed in Figure 2, with the terminals in banks 2 to 5 connected to energize clutch coils *H*1 through *H*7 in the proper combinations. When a cutting operation is to be performed, data from the tape or manual selector switch steps the switch to the position corresponding to the maximum allowable cutting rate. To see what happens, assume that the maximum permissible cutting rate is 10 in. per min corresponding to feed number 9 on Figure 2 and to position 9 on the stepping switch of Figure 8 (shown dotted).

If the distance from the final programmed position in the direction of cutting is sufficient to place the error in the coarse or medium-coarse speed range, feed rate relay 1*FD* in Figure 6 will be energized, nominally calling for a feed rate of 120 in. per min. But this command is modified because of the feed rate limitation imposed by the position 9 location of the stepping switch. Range relay 2*RR* is energized through a NO contact on 1*FD* and bank 1 of the stepping switch. This disables the last two rows of the slowdown matrix by opening the NC contact of 2*RR* and at the same time closes range control relay *RCR*. The latter energizes banks 2 to 5 of the stepping switch, transferring clutch control from the slowdown matrix to the switch. Clutches *H*1, *H*2, *H*5, and *H*7 are energized, giving the 10 in. per min feed rate specified for feed number 9 as shown in the tabulation of Figure 2.

As the distance to the programmed position decreases, the medium speed range is entered, nominally calling for a feed rate of 50 in. per min by energizing feed rate select relay 2*FD*. But since this is still higher than the allowable cutting speed, the slowdown matrix is disabled just as before (this time energizing 2*RR* through NO contact of 2*FD*), and the stepping switch still controls feed rate.

When the medium-fine speed range boundary is crossed, feed rate select relay 3*FD* is energized calling for a feed rate of 3.3 in. per min. Under this condition none of the range relays in Figure 8 is energized and the slowdown matrix resumes control, dropping the feed rate to 3.3 in. per min by the four NO contacts of 3*FD* energizing clutches *H*1, *H*2, *H*6, and *H*7. The slowdown matrix maintains control until the final position is reached.

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2. *31 NUMERICALLY-CONTROLLED POINT-TO-POINT POSITIONING SYSTEMS—FARRAND CONTROLS, INC. SYSTEM*, J. D. Cooney and B. K. Ledgerwood, "Control Engineering", January 1958, p. 88.

Formulas for Transistor Dissipation During High Frequency Switching

E. J. CURRENCE and J. A. WHEELER, Maico Electronics, Inc.

In low frequency switching applications it may be safe to ignore powers dissipated during rise and fall times when calculating the heating effect. But in high frequency switching these powers can easily exceed the "steady state" dissipations and so must be calculated. Here are equations that account for the dissipations during three different types of rise and fall curves encountered in commonly used transistor circuits.

The power handling capacity of a transistor depends largely upon the maximum temperature which the junction material can withstand. The maximum junction temperature is the temperature at which the reverse saturation current becomes large enough to cause thermal runaway or the temperature at which the density of thermally excited carriers becomes great enough to prevent transistor action. Unless the heat generated at the junction due to losses can be efficiently conducted away, the junction temperature will quickly exceed the maximum. Therefore, there is a relationship between the maximum power and maximum temperature for a given transistor. Since transistors are basically low power, heat sensitive devices, it is important to determine the exact power dissipated during operation.

The transistor is a nearly ideal switch because of its low voltage drop at high currents in the "on" condition and its very low leakage current at relatively high voltages in the "off" condition. In low frequency switching applications where the rise and fall times during the switching action are only a very small part of the total switching cycle, the total power dissipated in the transistor is practically equal to the sum of the dissipation in the "on" state and the dissipation in the "off" state. That is,

$$P_{total} = V_{ce\,sat} I_c + E_c I_{cer}$$

Where $V_{ce\,sat}$ = "on" collector to emitter voltage at saturation
I_c = collector current
E_c = collector supply voltage
I_{cer} = "off" leakage current

But in high frequency switching applications the rise and fall times of the switching action may become an appreciable part of the total switching cycle, considering that power dissipation is highest in the active region between the "on" and "off" states (Reference), and the power dissipated during the rise and fall times may even exceed that during the "on" and "off" states. The power dissipated during the rise or fall times is the integral of the $V_c I_c$ product during these times.

Equations are derived below for each of three rise and fall curves commonly encountered in practice. The rise and fall curves are integrated between their 10 percent and 90 percent points in keeping with the standard definition of exponential rise and fall times.

Linear rise and fall of collector current and voltage

Transistor parameters and circuit conditions may be chosen to give linear rise and fall characteristics; however, this method is more commonly a result of arbitrarily assuming the rise and fall time as linear for simplicity. Figure 1A shows a general circuit and Figure 1B, the linear current and voltage rise or fall relationship.

Average power dissipated from $t = 0$ to $t = T$ is:

$$P_{ave} = \frac{1}{T} \int_{t=0}^{t=T} E_c I_c \, dt$$

From the equations in Figure 1B

$$P_{ave} = \frac{E_{c\,max} I_{c\,max}}{T} \int_{t=0}^{t=T} \frac{t}{T} - \frac{t^2}{T^2}$$

Fig. 1

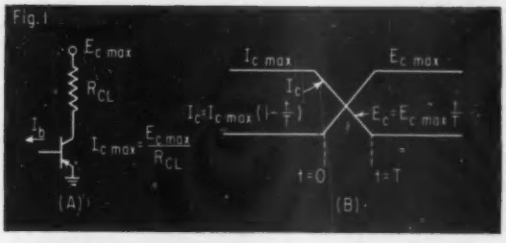
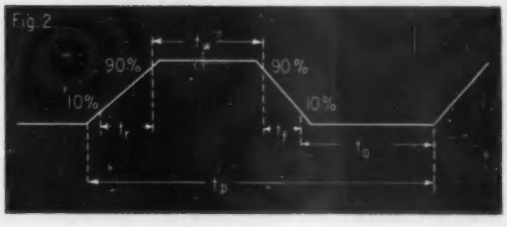


Fig. 2



and $$P_{ave} = \frac{E_{c\,max} I_{c\,max}}{6}$$

Rise and fall times are measured from 10 percent to 90 percent so the above result should be multiplied by 1/0.8, which gives:

$$P_{ave} = 0.208\,(E_{c\,max} I_{c\,max})$$

Using the various times as shown in Figure 2, the total power per cycle is:

$$P_{total} = \frac{(E_{c\,max})^2\,(0.208)(t_r + t_f)}{R_{CL}\,t_p} + \frac{(I_b\,E_{b\,sat})[1.2\,(t_r + t_f) + t_w]}{t_p} + \frac{I_{cer}\,E_{c\,max}\,t_o}{t_p} + \frac{t_w\,(E_{c\,max} - E_{c\,sat})\,E_{c\,sat}}{R_{CL}\,t_p} \qquad (1)$$

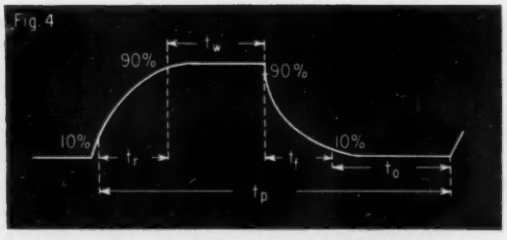
The four terms of the equation represent the following power dissipations:

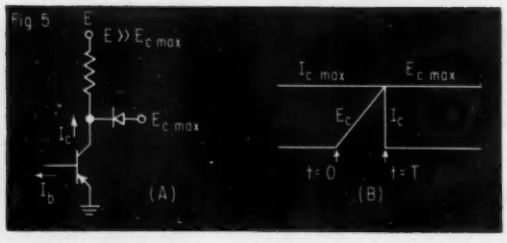
- The first term is the average collector dissipation during the pulse rise and fall times.
- The second term is the average base dissipation when the transistor is conducting.
- The third term is the average collector dissipation resulting from the leakage current when the transistor is off.
- The fourth term is the average collector dissipation during transistor saturation.

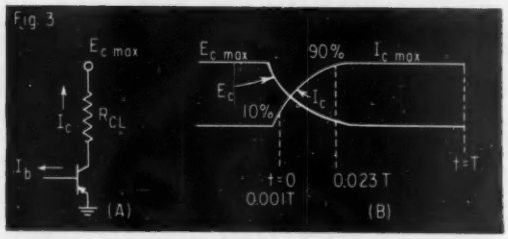
Exponential rise and fall of collector current and voltage

The switching times of a circuit are related to the transistor parameters and the circuit conditions. The collector current normally follows an exponential rise determined by the relationship between transistor current gain and frequency response. Distributed capacitances external to the circuit, such as wiring capacitance, change this exponential rate of rise. Since most switching circuits exhibit exponential characteristics, this equation will usually be the most applicable. Figure 3A shows a general circuit; Figure 3B, exponential current and voltage relationships.

The average power dissipated from $t = 0$ to $t = T$ is the $E_c I_c$ integral divided by the period, as before.







If it is calculated for an interval of 100 time constants of the exponential curve, that is, using

$$E_c = E_{c\,max}\,e^{-100t/T} \text{ and } I_c = I_{c\,max}\,(1 - e^{-100t/T})$$

then $$P_{ave} = \frac{1}{200}\,E_{c\,max} I_{c\,max}$$

Since the rise time is measured from 10 percent to 90 percent, this result must be multiplied by $1/(0.023 - 0.001)$, see Figure 3:

$$P_{ave} = E_{c\,max} I_{c\,max} \frac{1}{200\,(0.022)} = 0.228\,E_{c\,max} I_{c\,max}$$

Figure 4 shows a typical pulse with the various times indicated. The total power per cycle is:

$$P_{total} = \frac{(E_{c\,max})^2\,(0.228)(t_r + t_f)}{R_{CL}\,t_p} + \frac{(I_b\,E_{b\,sat})[1.2\,(t_r + t_f) + t_w]}{t_p} + \frac{I_{cer}\,E_{c\,max}\,t_o}{t_p} + \frac{t_w\,(E_{c\,max} - E_{c\,sat})\,E_{c\,sat}}{t_p\,R_{CL}} \qquad (2)$$

The four terms of the equation are as before.

Constant collector current with linear rise and fall of collector voltage

Sometimes a circuit is used that provides constant collector current and appears to have a linear rise and fall of the collector voltage as in Figure 5A. The resulting waveforms are in Figure 5B.

Again integrating $E_c I_c$ over the period:

$$P_{ave} = \frac{I_{c\,max}\,E_{c\,max}}{2}$$

And for rise and fall times from 10 percent to 90 percent, multiplying by 1/0.8 gives

$$P_{ave} = I_{c\,max}\,E_{c\,max}\,(0.625)$$

With the various cycle times as shown in Figure 2, the total power per cycle is:

$$P_{total} = \frac{(I_{c\,max}\,E_{c\,max})(0.625)(t_r + t_f)}{t_p} + \frac{I_b\,(E_{b\,sat})[1.25\,(t_r + t_f) + t_w]}{t_p} + \frac{I_{cer}\,(E_{c\,max})\,t_o}{t_p} + \frac{t_w\,(E_{c\,sat})(I_{c\,max}) + 1.25\,(t_r + t_f)(E_{c\,sat})(I_{c\,sat})}{t_p}$$

The four terms again represent the same dissipations as in Equation 1.

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1. *POWER SWITCHING WITH JUNCTION TRANSISTORS*, A. N. DeSautels, "Control Engineering", November 1959, pp. 113-117.

Sizing Analyzer Sampling Lines

THE GIST: Too much transportation lag in a sample line reduces the effectiveness of a stream analyzer by increasing over-all response time and reducing process controllability. Fast analyses can be assured by following simple, basic rules when designing and installing sample lines.

E. A. HOUSER, Beckman Instruments, Inc.

The transportation time, or purge time, of a sample gas or vapor between process and analyzer is directly proportional to the absolute pressure in the line. More specifically, purge time equals the sample line's total volume divided by the sample flow rate measured at actual conditions of pressure and temperature. Generally the temperature factor can be ignored. The actual flow rate is:

$$F_A = F_S \left[\frac{15}{P + 15} \right]$$

and the purge time is:

$$t = \frac{VL}{F_A}$$

where: V = tubing volume, cu cm/ft
L = total length of tubing, ft
F_S = flow rate at standard conditions (15 psia, 70 deg F), cu cm/min
F_A = flow rate at actual conditions, cu cm/min
P = sample line pressure, psig
t = purge time, min

Combining these equations, the purge time under actual conditions becomes:

$$t = \frac{VL}{F_S} \left[\frac{P + 15}{15} \right]$$

Installation example

Consider the following problem. The sample line is copper tube, ¼-in. diam with 0.030-in. wall, having—according to the table—a volume of 5.5 cu cm/ft. Line length is 100 ft. The sample flows at a rate of 2,000 standard cu cm/min. The pressure at the (process) sample takeoff point is 435 psig, which must be reduced by a pressure regulator to the 15 psig required by the analyzer.

Pressure regulator location plays an important role in the resulting purge time. If the regulator is mounted at the analyzer, for convenience of adjustment, the transportation time is:

$$t = \frac{5.5 \times 100}{2{,}000} \left[\frac{435 + 15}{15} \right] = 8.25 \text{ min}$$

However if the regulator is mounted at the sample point, the transportation time is only:

$$t = \frac{5.5 \times 100}{2{,}000} \left[\frac{15 + 15}{15} \right] = 0.55 \text{ min}$$

Thus, where minimum time lag is important, reduce the sample pressure at the process location. An alternative is to provide a higher flow rate of sample to the analyzer, but perhaps at higher operating cost because of the value of vented product.

Handling vaporized liquids

Often the stream is a liquid which must be vaporized for analysis by the instrument. Liquid holdup in sampling system components and line can seriously increase transportation time to the gas analyzer unless good installation practices are observed. The conventional method of taking a liquid sample from the process by attaching a 600-lb. standard gate or globe valve to a ½ or ¾-in. half-coupling welded in the line will introduce volume holdups of 50 cu cm or more. For light hydrocarbons the ratio of vapor volume to liquid volume is 200 to 300, so that a vapor flow rate of 2,000 cu cm/min corresponds to 6 to 10 liquid cu cm/min. Said another way, each 6 cu cm of liquid holdup means a 1-min delay from process to analyzer.

When handling liquids, therefore, reduced transportation time is accomplished by keeping short the liquid line between the process and vaporizer. Furthermore, to minimize liquid inlet volume holdup, a small instrument-type shutoff valve should connect the sample point directly to the vaporizer. If the vaporizer is too heavy, mount it independently and connect it to the valve via a short length of ⅛ x 0.30 tubing.

Sample line selection is thus first a matter of determining the permitted sample transport time at the required flow rate consistent with available pressure drop. In calculating over-all time lag, add the estimated volumes of components to the volumes for the commonly used sample lines shown in the table. When the ratio of length to diameter of a volume is less than 10, multiply the estimated volume by two or three to allow for mixing. The equation

$$t = \frac{VL + C}{F_S} \left[\frac{P + 15}{15} \right]$$

permits calculating the transportation time for each part of the system flowing at the same rate and pressure. Here, the modified components volume C takes into account the effect of mixing. Portions of the system at different pressures and those containing liquids should be calculated separately and summed to obtain the over-all transportation time.

Common Sample Lines for Stream Analyzers

Size	Volume, cu cm/ft	Purge time per 100 ft*
Tubing—		
⅛ × 0.030 wall	0.65	3.9 sec
⅛ × 0.020 "	1.1	6.6 sec
¼ × 0.030 "	5.5	33.0 sec
⅜ × 0.035 "	14	1.4 min
½ × 0.035 "	29	2.9 min
⅝ × 0.049 "	43	4.3 min
¾ × 0.049 "	66	6.6 min
Pipe—		
⅛ Sch 40	11	1.1 min
¼ " "	21	2.1 min
⅜ " "	38	3.8 min
½ " "	60	6.0 min
¾ " "	105	10.5 min
1 " "	170	17.0 min

* Standard flow rate of 2,000 cu cm/min at 15 psig.

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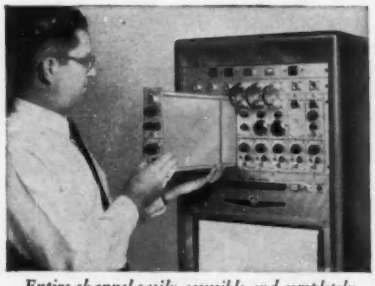
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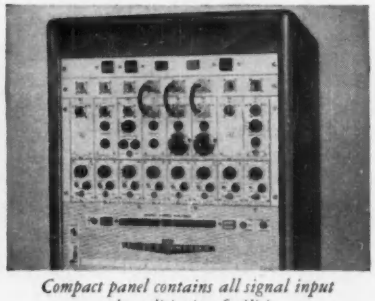
Band Amplitude Product (i.e. Bandwidth times Amplitude) is 5600...140 cps (3 db point) x 40mm! TRACE-MASTER can provide meaningful signal information in areas never before possible with direct-writing recorders!

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Compact panel contains all signal input and conditioning facilities.

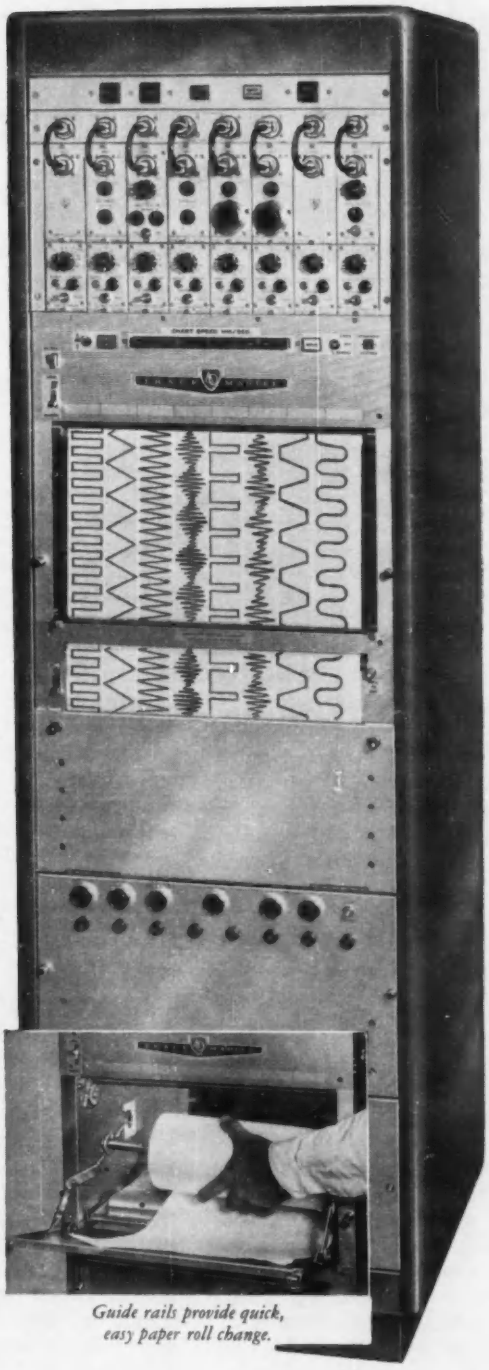


Platen tilts to convenient writing angle.

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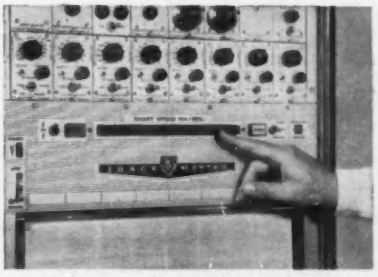


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CIRCLE 131 ON READER SERVICE CARD 131

Bistable Jump Circuit for Static Switching

One of the most intriguing of all electrical phenomena is the jump action in a ferroresonant circuit. The author describes this action as applied to a static switch and suggests that the time is favorable for reevaluating the principle of ferroresonance. The incentives for developing such switches include their high load capacity, low cost, and the ability to handle ac loads directly.

PHILIP J. WALSH
San Francisco

The feasibility of applying the phenomenon of ferroresonance to electrical switching was recognized some years ago. However the concept was never fully exploited—possibly because of suspected sensitivity to disturbances in supply voltage or frequency. In addition, the transient conditions involved in ferroresonant switching are difficult to analyze fully, making it correspondingly hard to formulate rigorous design procedures.

In his persistant investigation of this phenomenon over the years, the author has found that the fears of instability never became an actuality. Disturbances in supply voltage and frequency are comparatively rare in modern power systems. And the power supply design art has advanced considerably so that now it is a simple matter to provide an accurately regulated, packaged voltage source for control applications in areas of undependable electrical service.

Study and experimentation have also served to shed enough light on the jump phenomenon for the author to obtain a broad patent* on the mechanism of switching. Laboratory models based on the patent have demonstrated predictable and consistent performance. Thus, this appears to be a favorable time for control designers to reevaluate the ferroresonant switch. There are sufficient benefits at stake to make this investigation well worthwhile. The switch is static, a true ac device, and can handle power loads directly. Because ordinary electrical-grade steels and standard transformer construction are involved, the ferroresonant switch should have appreciable cost advantages over magnetic amplifier types of static devices which require special materials.

* U. S. Patent No. 2,738,458

The switching transformer in the circuit of Figure 1 contains a three-legged core of standard electrical-grade silicon steel. There are three windings on the core: the signal coil, the center or load coil, and the trigger coil. The load coil is wound for a higher voltage than the trigger coil, and the cross section of its core leg is greater than that of the trigger leg. A capacitor completes the circuit between the load and trigger legs. When the signal voltage is below the jump point or when the loop is open-circuited, the voltages developed in the two coils of the loop oppose one another. The load coil is wound to develop a higher voltage than does the trigger coil, so that the voltage across the capacitor is the difference between the bucking coil potentials. The capacitor rating is such that for low values of current the combined capacitor-trigger coil impedance is inductive. Under these conditions, moreover, the output voltage developed across the load coil is very low.

Jump phenomenon

With rising input voltage the current through the trigger coil increases, causing its inductance to drop because of increased saturation of its core. When the inductive reactance becomes equal to the capacitive reactance, the loop reaches the point of resonance. Then the loop current becomes very large, further decreasing the inductive reactance of the circuit and making the effective impedance of the series circuit capacitive. The reactive component of current in the loop circuit therefore reverses in phase, and the two coil voltages now boost rather than buck. At the instant this occurs, the voltage across the load coil suddenly jumps from its previous very low value to a relatively high value. The increase in voltage can be from 10 to 20-fold. The voltage across the trigger coil also jumps but not to

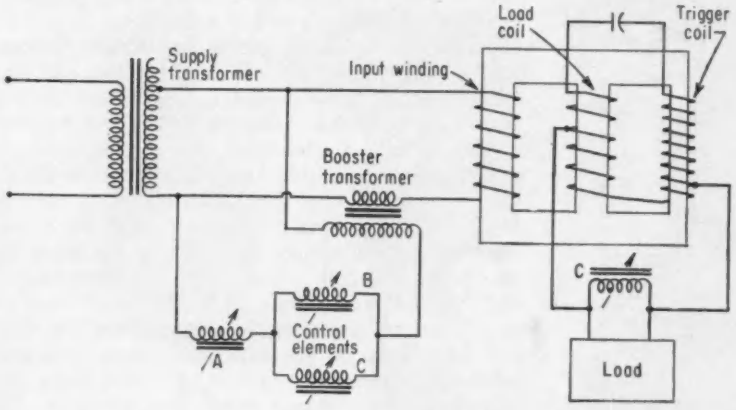


FIG. 1. Schematic diagram illustrating the principle of ferroresonant switching.

the same extent—ordinarily only from 20 to 50 percent. The primary effect on this latter coil is a sudden reversal of phase.

With falling signal voltage, conditions are reversed. Because initially the two coil voltages are additive, sufficient current flows to maintain the inductance of the trigger coil below its resonant value even when the jump point is reached. The voltage must fall below this point before resonance occurs to cause the break.

Superimposed on the effects just described are others due to loading either of the coils in the loop. When no load is drawn from either, the critical points are widely separated. As load is increased, the jump and break points rise simultaneously on the voltage scale and approach one another. Loading the center coil affects the jump point only slightly but raises the break point; loading the trigger coil raises both. Thus by proper choice of load the separation between the points can be made anything desired. This is illustrated in Figure 2 containing plots of current vs voltage for the signal winding. In Figure 2A the transformer is so loaded as to bring the jump and break points close together. In Figure 2B the points are widely separated and occur at lower input voltages than under heavy load conditions.

It is possible to place the load circuit across a portion of both the load and trigger coils and thus secure substantially zero voltage output for input voltages below the jump point. One transformer delivered 15 volts across the load coil just below the jump point and then 230 volts immediately following the jump. Just before the jump the load coil delivered about two-thirds of the voltage developed above the jump point. By tapping the trigger coil at the proper point it is possible to supply a bucking 15 volts before the jump to maintain a zero load voltage. After the jump the two coils boost instead of buck so that 20 volts are added to the 230 volts from the load coil, and the output voltage becomes 250 volts.

Signal windings

Power for operating the load is derived from a source of substantially constant voltage. In certain cases this may be a standard control transformer energized from the usual 60-cycle, commercial power supply. For extremely accurate controls, particularly those involving low level input signals, it is preferable to use a voltage regulated supply. The secondary winding of the control transformer is connected to the input winding of the ferroresonant relay through the secondary of a small booster transformer. The latter is a low voltage, low power device with secondary conductors of sufficient cross section to carry full load current to the relay. The primary winding of the booster transformer is connected to the voltage source through one or more variable impedance elements. It is these elements that serve as the means of entry for control signals and that collectively form the logic circuits for AND and OR functions.

For maximum sensitivity and accuracy of control, the jump and break points of the ferroresonant relay should be close together. It is easy to adjust the device to its normal load so that these points are separated by only 1 or 2 volts. A typical circuit, for example, could be designed to jump at 101 volts and break at 99 volts. In Figure 1 variable impedance elements *B* and *C* represent OR logic while the combinations of elements *A* and *B* plus *C* have an AND relationship. An indefinite number of AND and OR events can be accommodated by the system.

The input device has been referred to as a "booster" transformer, implying that its voltage aids

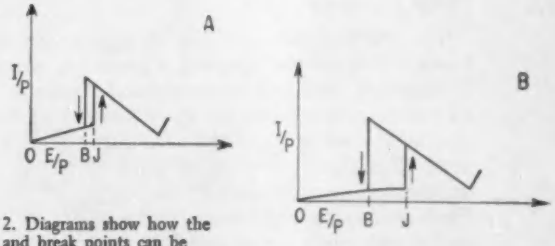


FIG. 2. Diagrams show how the jump and break points can be brought closer together or farther apart by proper choice of load.

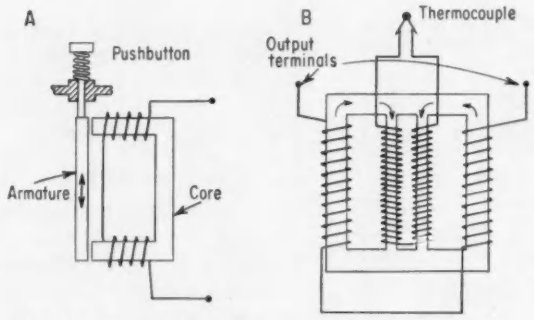


FIG. 3. Two types of variable impedance devices that can be used as input elements for a switching transformer.

that of the control transformer. This is not a necessary condition, however, and if other parameters of the circuit are changed slightly, the input transformer could be connected in bucking relationship. A typical turns ratio for the stepdown input transformer is 25 to 1. If its primary is connected directly across a 100-volt source, it boosts the voltage across the relay input coil by 4 volts. The reactance of each of the elements *A*, *B*, and *C* is equal to the input impedance of the booster transformer. If *A* is the only element effectively in the circuit, the supply voltage divides equally across reactor A and the booster transformer, which then delivers 2 volts to the relay input winding. Under the conditions assumed a tap on the supply transformer is chosen to deliver 97 volts, which added to the boost voltage brings the voltage across the relay input winding to 99 volts, or just below the break point of the circuit. And when both elements *B* and *C* are also in their high impedance condition, the boost voltage is still lower.

Elements *A*, *B*, and *C* are selected with a fairly large ratio of maximum to minimum impedance—at least four to one and preferably higher. Assuming a value of four to one, when the reactance of element *A* is reduced to its minimum, the voltage rises slightly —about a third of a volt—above the break point, but not as far as the jump point. If either element *B* or *C* is changed to its minimum reactance condition, however, the voltage delivered by the booster transformer will exceed the additional 2 volts necessary to cause the jump.

Input elements

The reactors may take any of a large number of forms. One of the simplest, Figure 3A, comprises a horseshoe core and a symmetrical winding. The movable armature can be positioned so as to substantially open or close the magnetic circuit of the core. For short gaps the effective reactance is approximately proportional to the length of the gap. Thus by moving the armature, the reactance of the device can easily be changed by much more than the prescribed ratio of four to one. The armature may be part of a pushbutton or limit switch, and it can be made to rotate as well as slide.

Figure 3B shows a variable impedance element having four wound legs. Each of the two end legs carries one-half of an output winding whose inductance is to be varied. The two center legs support a winding that is connected to a sensing element, a thermocouple in this case. The outer windings are so connected that their fields are in opposition. With no current from the thermocouple, the center legs serve as low reluctance paths for the fields set up by the end coils. Thus the impedance of the end coils is at a maximum. However when thermocouple current saturates the center cores, the end coil fluxes have no low reluctance return path and substantially neutralize each other. This drops the impedance of the output circuit to a low value.

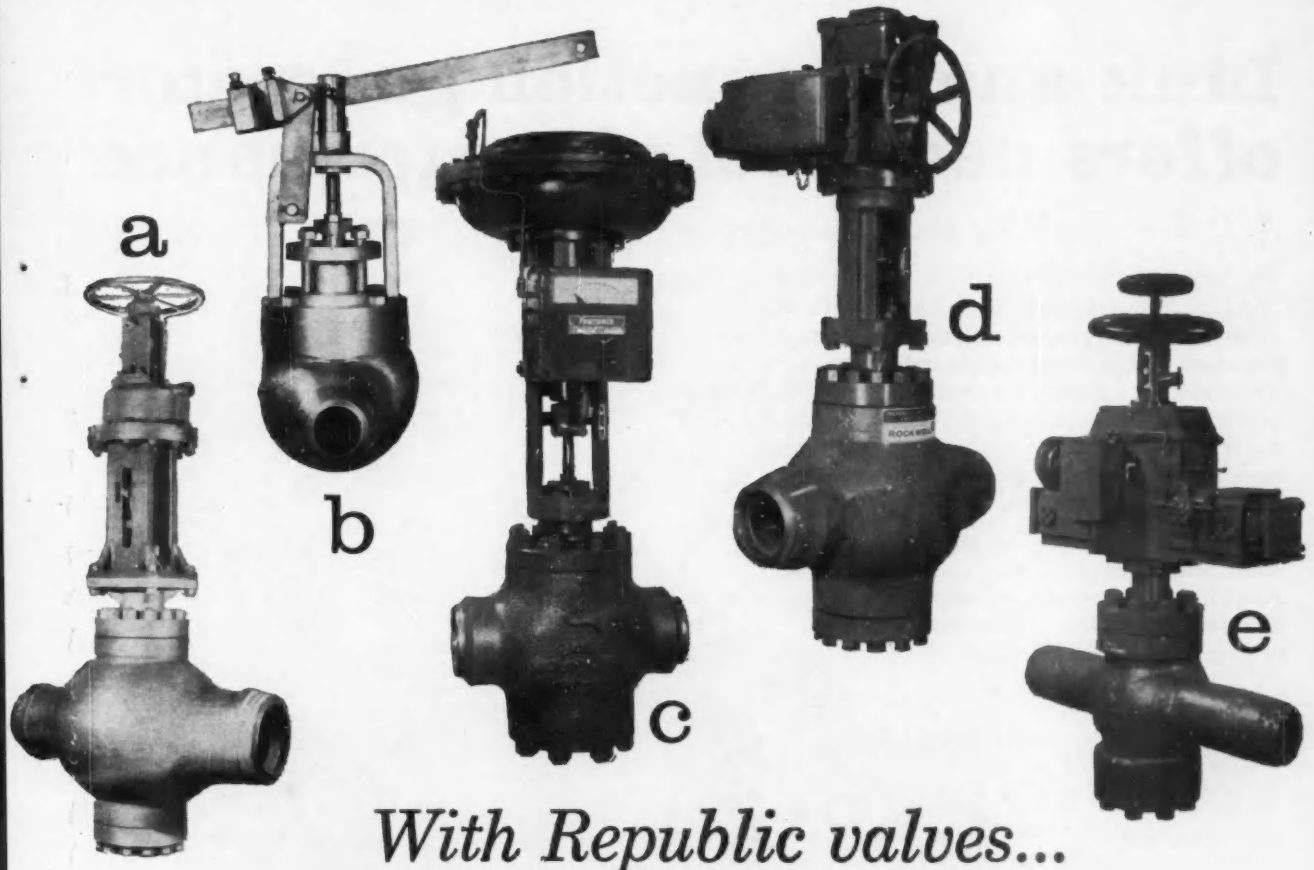
Variable-resistance elements may be used in the logic circuits. However they are not, in general, as sensitive to small voltage variations as are reactances, because they cause a phase shift in the voltage developed in the booster coil. Despite this fact, resistive elements such as thermistors and varistors can substitute directly for reactors A, B, and C or control the reluctance of a small auxiliary reactor.

NOT generator

It has been stated that the secondary of the signal input transformer may be arranged to buck instead of boost. Operation in this case reverses; the circuit jumps when the impedance in the controlling elements is high (dropping the bucking voltage) and breaks when the low impedance state is resumed. For AND logic the signal elements must be placed in parallel and for the OR function, in series.

It is possible, moreover, to combine the buck and boost configurations. The auxiliary signal transformer may be provided with two primary windings connected in opposition, each supplied through an individual control impedance or impedances. The impedance connected to the bucking winding must normally be very high—almost infinite, like that of an open-circuited switch. When the switch is closed or the impedance is otherwise reduced to a low value, the bucking winding can be adjusted to override the boosting winding. So connected, it becomes a very effective NOT function generator. Other types of differential connections may be employed. In general, they will result in making the boosting (or bucking) voltage zero under no load conditions, when neither positive (AND or OR) nor negative (NOT) signals are applied.

At times it is preferable to generate the NOT function by means of a variable impedance element connected across the load. The current carried by this element in its low impedance state is made high enough so that it overloads the device, causing it to "break" and reduce the output voltage substantially to zero. The element used can be of any of the types already considered, connected across the load as at *C* in Figure 1 or across the trigger coil.



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Input/Output:	± 100v DC into 10,000 ohm
Accuracy:	± 1% of full scale
Resolution:	0.02% of full scale
Drift:	Less than 0.04% during one minute Less than 0.1% during eight hours
Frequency Response:	Better than 5 cps for output amplitude with ± 1% and phase error max. 5 degrees

Power requirements:

Standard:	± 28v ± 10% DC Average: 50 watts Maximum: 120 watts
Optional:	110v, 60 cps

Function specification:

Continuous, single valued with maximum output change ± 10v for an independent variable variation of ± 1v.
Representation accuracy:
441 points on 21 x 21 matrix.

Physical characteristics:

Size:	8¾" x 19" x 15½"
Weight:	50 pounds
Cabinet:	Independent unit or can be mounted on a standard 19" instrument rack.

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Air Expansion Powers New Actuator

HENRY W. KOGAN
Detroit Controls Div., American-Standard

A new air expansion system has been developed for remote automatic metering and dispensing of liquids. It was designed and developed specifically for handling laundry products in automatic home washing machines but can be adapted to any equipment where metering and dispensing of liquids is essential (like drink vending machines). Air was chosen as the control medium for simplicity, reliability, and versatility.

Figure 1 shows a cross section through the new actuator. A plastic housing is divided into two airtight chambers by a rubber diaphragm. The air in the larger chamber is heated by a resistance unit of special low temperature, low mass, wide distribution design and expands to displace the diaphragm a calculable amount. The smaller metering chamber is connected to an airtight liquid reservoir by a flexible tube. A volume of liquid is dispensed from the reservoir proportional to the volume of air discharged from the metering chamber.

Impulsing principle

A technique of impulsing the actuator has been adopted to keep the size of the actuator within practical limits. Impulsing also makes it possible to use the same actuator to dispense several different liquids in independently selected quantities. With this concept the output of the actuator per "pulse" (a timed heating period of several seconds) is fixed, and the total amount of the liquid to be dispensed must be a multiple of this fixed output. In one washer to which the dispenser has been applied, for example, the actuator meters 2 oz per impulse. If the user decides that 8 oz of bleach are required, the dispenser operates four times in quick succession at the proper time.

The amount of liquid to be dispensed is selected by a printed circuit slide switch which energizes four printed impulsing switches that close momentarily in sequence, see Figure 2. The actual making and breaking of the circuit to the heater is done by a cam actuated flutter switch to prevent arcing on the printed circuit board. The dispenser timer motor is distinct from the main washer timer and is contained in the dispenser control unit with the printed board and cams which it drives. The control unit also houses volume selector switches and a diverter valve.

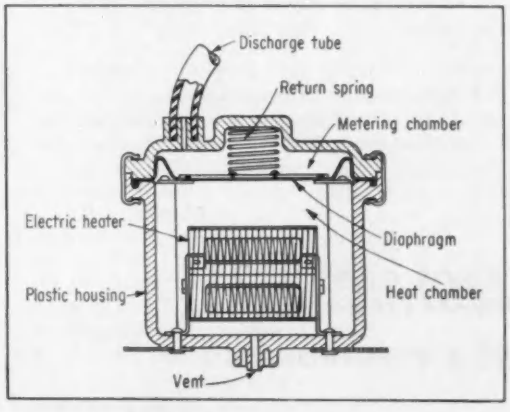
In the dispenser system for the washer mentioned, two liquid reservoirs are used, one for bleach and one for a fabric conditioner. The diverter valve is cam operated to connect the discharge chamber of the dispenser actuator to the bleach reservoir during the first 180 deg of cam revolution and to the other reservoir during the last 180 deg. The dispenser motor is started at the right time in the washer cycle by a pulse from the main timer. The motor circuit is then continued through a track on the printed circuit which is interrupted after one full revolution, which takes 2 min.

The switch at the upper left in Figure 2 is also set by the master timer and determines which of the two liquids is dispensed during the dispenser control revolution. The control unit can be modified to dispense three or more liquids. The unit cancels the setting of the bleach selector after each revolution to prevent inadvertent addition to the next load.

In actual tests of the actuator it was found that the output remained remarkably consistent over a large number of cycles, and that for most liquids a cycle of 10 sec "on" and 5 sec "off" was sufficient to discharge a 2-oz volume. The heater used drew 75 watts. The short off-time is achieved by venting the large heating chamber in the actuator to atmospheric pressure and ambient temperature between heating impulses.

Recycling tests showed that the 10 percent tolerance on actuator output can be held even when the time between 8-oz cycles is only four or five seconds. Cooldown data indicates that heater chamber temperature drops more than 50 percent in less than two seconds between impulses. Temperature differences between actuator and reservoir resulted in little loss of accuracy. For a temperature difference of 20 deg F, the change in discharge volume was 3.6 percent.

FIG. 1. Simple actuator for dispensing liquids is divided into two chambers by rubber diaphragm. Heating air in closed lower chamber increases pressure to move diaphragm and discharge air from upper metering chamber. Venting lower chamber restores equilibrium quickly between heating cycles.



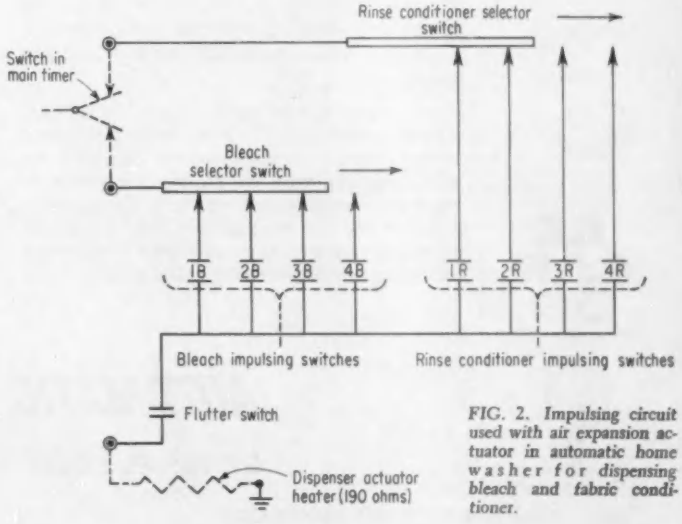


FIG. 2. Impulsing circuit used with air expansion actuator in automatic home washer for dispensing bleach and fabric conditioner.



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Frame Straightener Programs Bending Automatically

K. J. RHODES, A. O. Smith Corp.

The basic philosophy applied in straightening automobile frames is to clamp the frame at gage points, see Figure 1, and deflect the four corners as may be required to bring the corner heights to a tolerance of plus or minus $\frac{1}{8}$ in. The gage points are the locations used by the customer in checking frame dimensions and are just in front of the rear kick-up and to the rear of the front kick-up. The machine is provided with cylinders top and bottom at each of the corners to bend these corners into tolerance. The original intent was to make the operation manual with an operator at each corner. But it was questionable whether frames could be straightened at the desired rate with manual operation.

To speed up the straightening operation and to reduce manpower, an automatic cycle was designed to inspect and straighten the frames. For automatic inspection, four probes, one at each corner, are lowered onto the frame after the frame is clamped at the gage points. The four probes are each connected to a rotary cam limit switch through a rack and pinion. The rotary switch is provided with eight cams. Two cams indicate if plus or minus tolerance limits are satisfactory, and if not, a third establishes the direction of straightening (up or down.) Cam operated limit switches control five limits of deflection of corners of the frame to bring them into tolerance limits, Figure 3. The eighth causes the first two steps of straightening to be by-passed if original variance exceeds a prescribed amount.

The smallest limit of deflection is such that the resulting permanent set on the least rigid frame with a minimum out-of-tolerance in one direction will not leave frame out of tolerance in opposite direction. Each succeeding deflection is greater to accommodate greater manufacturing variances. With the five limits of deflection, errors in corner heights of plus or minus $1\frac{1}{2}$ in. can be brought into drawing tolerance of plus or minus $\frac{1}{8}$ in. With this arrangement all frames can be brought into tolerance in one or two and sometimes three straightening steps.

The automatic circuit is set up when

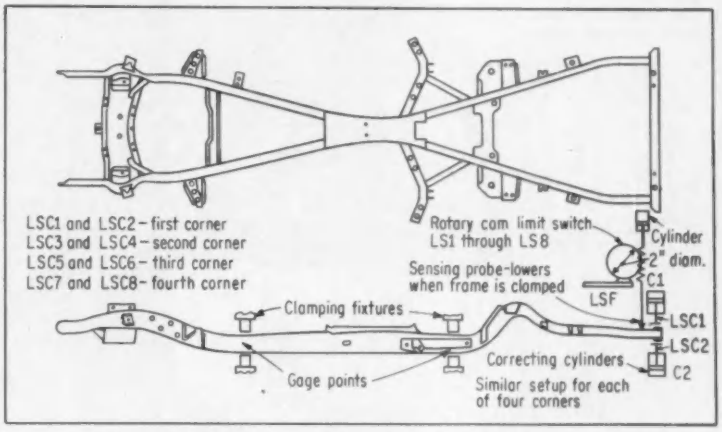


FIG. 1. Automobile frame showing gage points and rotary cam limit switch used for measuring degree of straightening required. Limit switches on correcting cylinders set up measuring circuits when all cylinders are withdrawn.

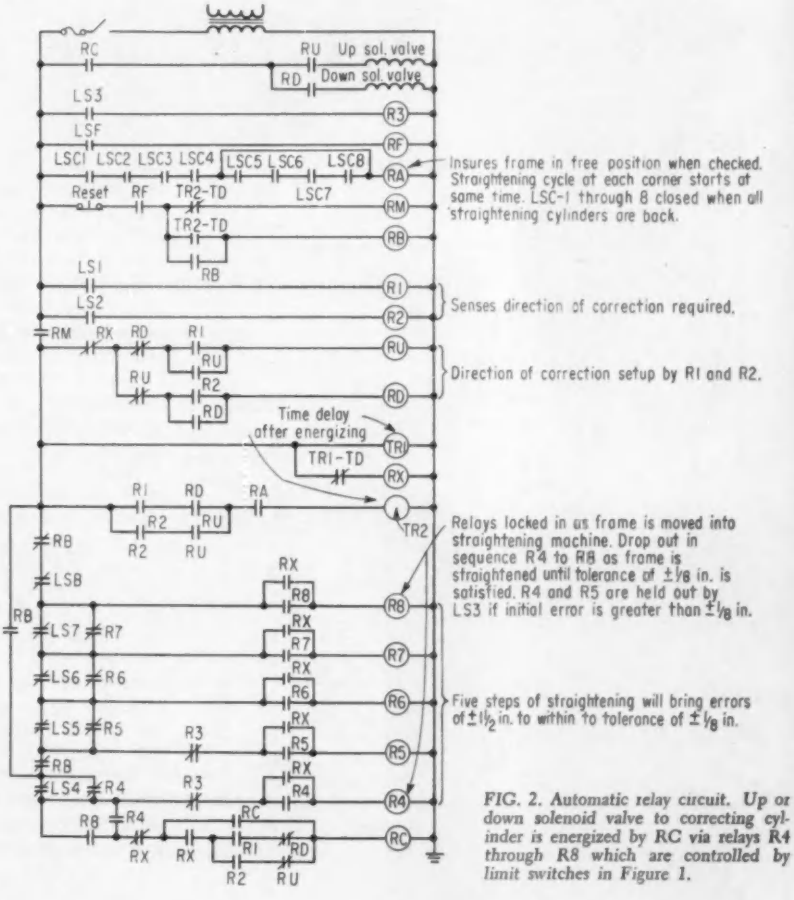


FIG. 2. Automatic relay circuit. Up or down solenoid valve to correcting cylinder is energized by RC via relays R4 through R8 which are controlled by limit switches in Figure 1.

the probes lower to the frame after clamping, Figure 2. A relay locks in either the up or down cylinder solenoid as directed by the tolerance limit cams. A relay for each deflection step is also locked in. After the circuit is set up, the first step of straightening for each corner starts simultaneously. The frame is automatically inspected after all straightening cylinders have returned. The second step of straightening starts simultaneously on corners needing additional straightening and continues until all corners are within tolerance. Figure 4 shows the machine with a frame not yet clamped.

FIG. 3.
Arrangement of rotary can limit switch used at each corner of frame.

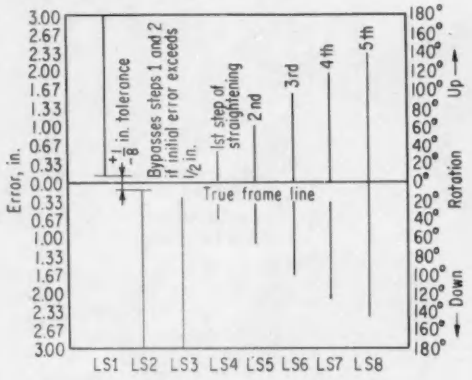
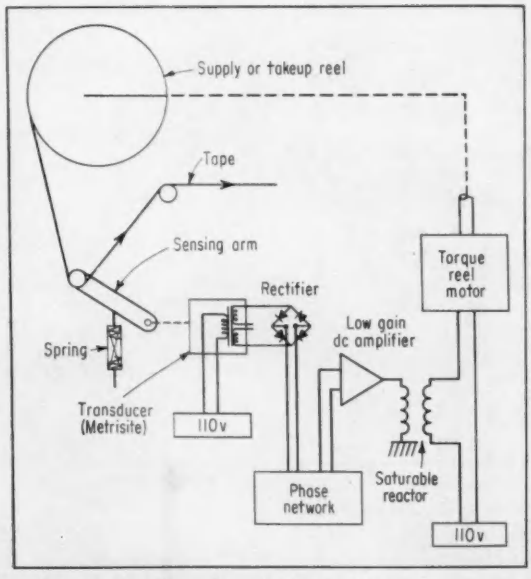




FIG. 4. Frame straightening machine with frame and correcting cylinders emphasized.

High Output Transducer Makes Tape Tensioning Simple

DONALD E. PIERCE
Brush Instruments Div., Clevite Corp.



High output transducer eliminates need for high gain amplifiers in this tape tensioning system.

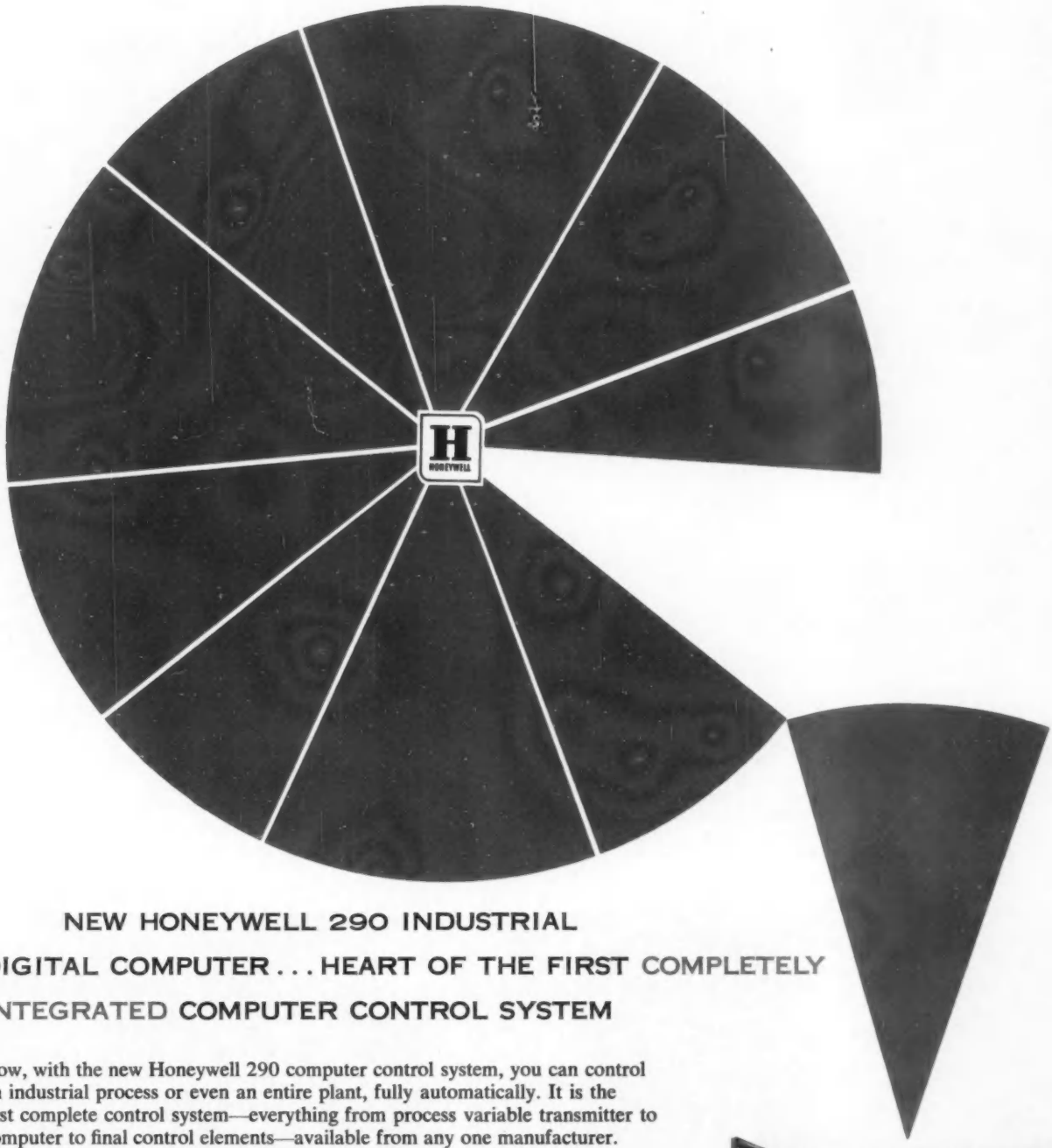
Tape tension must be closely regulated in a special high speed (240 ips) servo controlled tape transport developed to test laboratory and production models of magnetic recording and playback heads. The tape tension is controlled by two reel servos as shown in the accompanying figure. These servos have an over-all system response rate of 2 cps.

Two Brush Instruments Type 34 Metrisite angular motion transducers with output voltages ranging up to 50 volts are used to detect any variation in tape tension. The high output voltage eliminates the need for high gain amplifiers.

Tape from the supply reel is looped around a sensing arm attached to the armature of the transducer. The sensing arm is biased with a spring to 8 oz for ½-in. tape or 12 oz for 1-in. tape so that motion of the arm is actually a direct measure of tension in the tape. The tape is guided past the magnetic head and then to the takeup reel which has a control system identical to that of the supply reel.

The primary winding of the transducer is energized with 110 vac and the 25 to 50-vac output is rectified and fed into a phase network. The output to the phase network ranges from 15 to 30 volts. The phase network attenuates any frequencies which would create oscillations in the servoloop when the tape starts up or when excessive friction builds up between layers of the tape on the reel. Oscillations of the sensing arm may also occur as the tape reaches the end of the reel since the motor torque changes more rapidly. Due to the rapidly decreasing moment arm of the tape on the reel.

The phase network produces a high loop gain at running mode and a low loop gain at the starting mode. The output of the phase network goes to a low gain dc amplifier which controls a saturable reactor power amplifier.



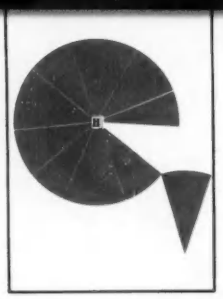
NEW HONEYWELL 290 INDUSTRIAL DIGITAL COMPUTER . . . HEART OF THE FIRST COMPLETELY INTEGRATED COMPUTER CONTROL SYSTEM

Now, with the new Honeywell 290 computer control system, you can control an industrial process or even an entire plant, fully automatically. It is the first complete control system—everything from process variable transmitter to computer to final control elements—available from any one manufacturer. Heart of the system is the new Honeywell 290 industrial digital computer.

The Honeywell 290 is the most powerful computer in its class, despite its small size, low cost and low power consumption. It performs, for example, 8,000 additions, 1,250 multiplications or 400 square root extractions per second. Unique, powerful macro-instructions help make the 290 easy to program, reduce working memory requirements and increase operating speeds. These special instructions augment the basic instructions, and eliminate many special subroutines.

The combination of high-speed operation and the reliability of conservative solid-state circuitry brings optimum control of many types of industrial processes. In addition, the Honeywell computer control system can compile complex operating guides, correlate data, and reduce huge masses of acquired data into immediately usable information for monitoring or optimizing process operations.





NEW HONEYWELL 290 INDUSTRIAL DIGITAL COMPUTER . . . HIGH SPEED, PARALLEL OPERATION, EASILY PROGRAMMED

The high computation speed of the Honeywell 290 provides many advantages in on-line monitoring and control of industrial processes:

- Higher sampling rates give closer control because each variable can be checked more frequently.
- More work can be accomplished in a given time.
- Checking and validity routines can be used extensively.
- Tasks other than process control can be accomplished either through time-sharing or through priority instructions in the computer program.

The Honeywell 290 is the first industrial digital computer to use parallel operation within the computer. All digits in a multi-digit number are transferred *simultaneously* from one element to another within the computer . . . in one count of the clock. Therefore a much slower clock rate can be used. Components are operated far below their maximum ratings—greatly increasing overall reliability, while permitting many thousands of program steps to be executed each second.

The computer combines both magnetic core and drum memory. Main memory is the magnetic core type, and it can be supplied with capacities of 1,024, 2,048 or 4,096 words. A magnetic drum memory with a capacity of either 4,096 or 8,192 words is also provided—a total capacity of 12,288 words. This combination gives you the speed and random accessibility of core memory with the program permanence of drum memory.

The Honeywell 290 Computer operates with standard, field-proved Honeywell process instrumentation in a completely integrated system of control. *ElectriK Tel-O-Set* transmitters feed process variable input data to the computer. These solid-state, two-wire transmitters convert temperature, pressure, flow and other measurements into electric signals. Various types of computer peripheral equipment are supplied by Honeywell to add flexibility to the system and make it easily expandable to meet future requirements. This equipment includes analog-to-digital and digital-to-analog converters, high-speed paper tape readers and punches, visual displays and electric typewriters. Honeywell *ElectriK Tel-O-Set* transducers make the computer completely compatible with existing pneumatic process measuring and control instruments.

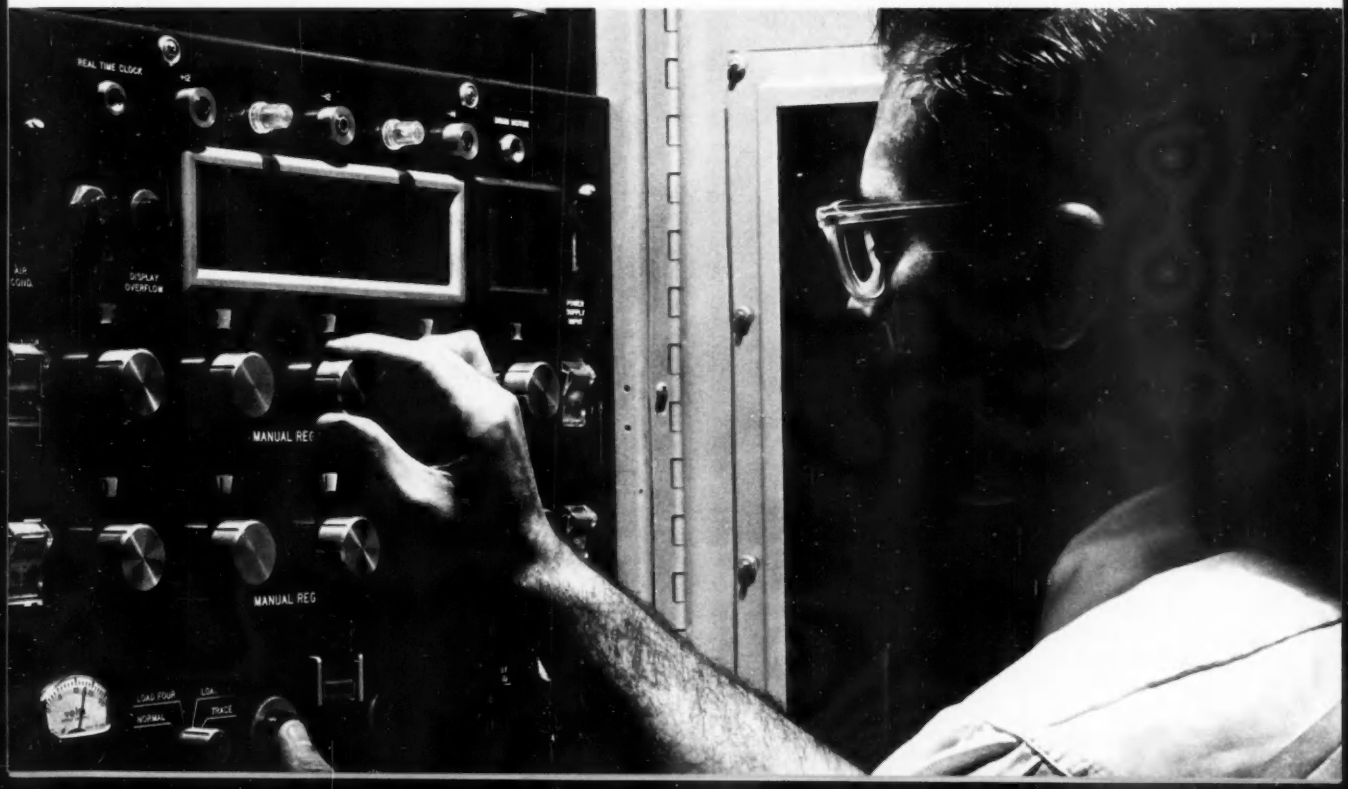
Get complete details from your nearby Honeywell field engineer. Or write for Catalog C-290. MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

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Measuring Tape Wrapped on Drum For Digital Encoding

A. M. HALL and S. LAPENSON
Electric Boat Div.
General Dynamics Corp.

Fifty-eight pairs of hydraulically driven ball screw jacks precisely determine the contour of the 100-ft long, 16-ft high, 3-in. thick stainless steel walls in the Air Force's new propulsion wind tunnel at Tullahoma, Tenn. The shape of the nozzle formed by these flexible walls must be controlled to an accuracy of 0.005 in. at each jack to obtain the desired airspeeds without turbulence. The temperature range over which the tunnel must operate is minus 10 to plus 575 deg F, so the system is temperature compensated.

Figure 1 shows the electrohydraulic servosystem used to position each jack. Any small variation in jack position causes the computer to send a signal to the servovalve which moves the wall to the correct position. Jack differences of a few thousandths of an inch beyond required tolerances could damage the steel walls, which took several years to fabricate, so the measuring system has to sense differences of 0.002 in. over a range of travel in excess of 7½ ft.

The sensing unit designed to fulfill these accuracy requirements consists of a rotating drum assembly, a gear reduction assembly, two digital encoders, and a low expansion coefficient Invar 36 measuring tape. These drum mounted tapes, Figure 2, are secured to the back side of the tunnel walls to indicate wall movement. The drum motion is picked up by the encoders and translated to a binary signal for the computer. Special high precision machined gears with antibacklash characteristics are used between the drum and the encoders. Two encoders are used: one is a fine reading unit which registers increments of 0.001 in., and the second is a coarse encoder which registers increments of 1.024 in. The fine encoder provides a Gray code reading and the coarse encoder, a nonambiguous binary.

Thermal growth can be four to six times greater than the total allowable system error and is carefully controlled. The hottest area in the positioning system is that closest to the flexible plates, so the tapes are connected to these walls by water-cooled compensator bars approximately three feet long. Temperature is reduced by controlled water at 100 deg F which flows through the bars at a rate of ¼ gpm. The tape and drum units are heated to a constant temperature of 150 plus or minus 15 deg F, sensed by thermistors and thermostats.

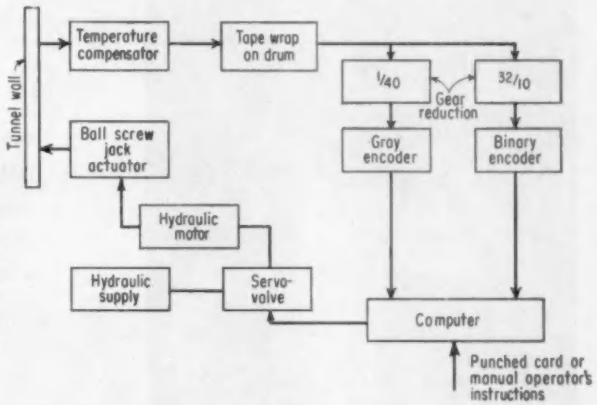


FIG. 1. Punched card input determines wind tunnel wall contour through servosystems like this on each of 116 hydraulic jacks. Temperature compensated wall position encoding system across top.

Tests showed that the nominal length of tape which could be used in a sensing unit was a function of the effective wrapping radius. In any stiff member subjected to external forces, the neutral surface is an imaginary longitudinal plane within the member. This plane of zero stress is located conventionally at the transition of internal stress from compression to tension. The neutral axis of the tape was determined to be three-tenths of the tape thickness from the side in compression. Drum diameter and corresponding gear ratios were then chosen which would give an equivalent count for every 0.001 in. of tape length. As it is necessary to permit a continuous transition from one wrapping radius to the succeeding one, a special tapered clamp was designed to connect the tape to the drum. On the basis of two points for each wrapping radius, Figure 3 is a typical plotted correction curve. The tape cross section and drum diameter were also chosen to reduce sag effects and maintain good frictional stability. Errors that are inherent functions of tooth to tooth gearing, tape tension, sag, and changes in wrapping diameter are compensated in the computer.

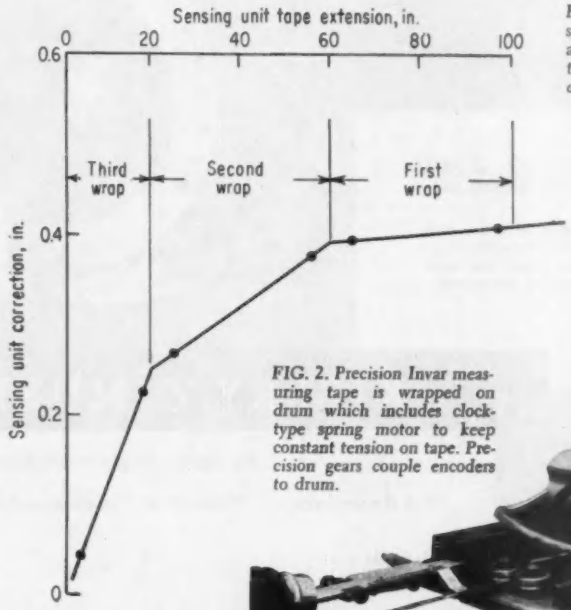


FIG. 3. Tape wraps up on special wedge-shaped clamp, and computer applies correction for changing wrap diameter as shown.

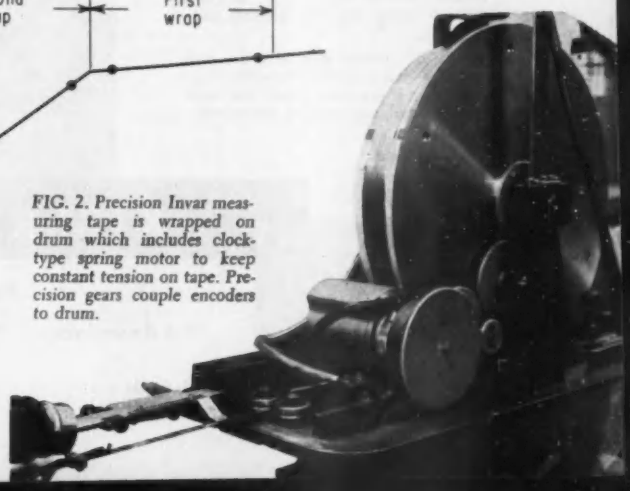
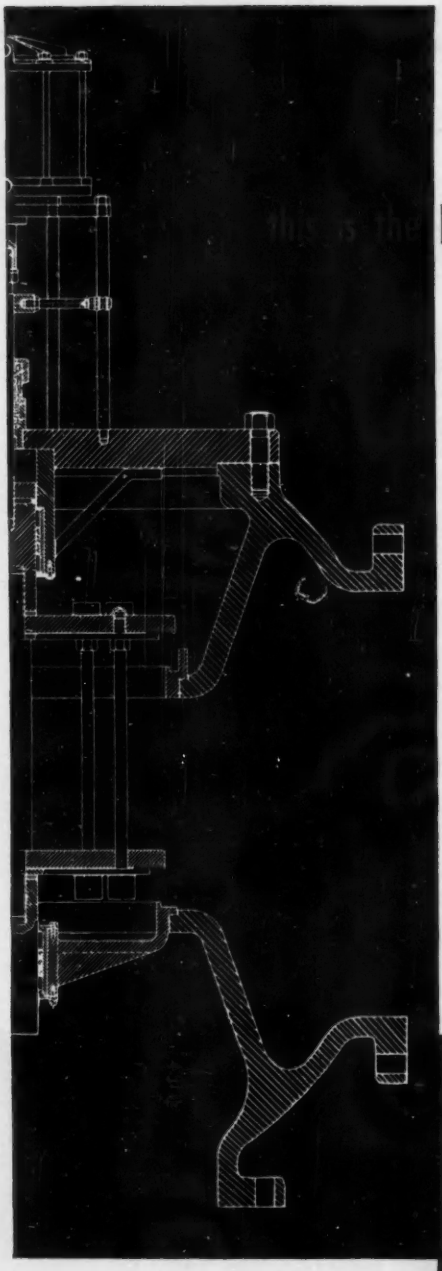


FIG. 2. Precision Invar measuring tape is wrapped on drum which includes clock-type spring motor to keep constant tension on tape. Precision gears couple encoders to drum.



this is the largest double-seated control valve ever made

When you are talking *big* control valves, talk to Kieley & Mueller. K&M is the largest manufacturer of the big ones, control valves above 16 inches. Standard globe-type valves are available in 20, 24, 30 and 36 inch sizes; even larger valves will be produced on special order.

This 36-inch double-seated angle valve closes snugly on giant Teflon seats. The inner valve positions responsively, gliding on special roller-slide bearings. It's massive, but is operates protected by a K&M patented torque resistor. Beyond the problem of size, this valve is mounted on its side, and it has been performing creditably for over four years.

BIG or small, if it's control valves, you'll like the pitch-in, helpful approach of your local K&M representative . . . plus capable engineering and manufacturing follow-thru at the K&M plant.

Write for Bulletin CV-53.



ABOVE: Partial cross-section of K&M 36-inch valve showing general construction.

AT RIGHT: Actual size of a 36 inch valve can be visualized from this illustration of a workman inside the valve body performing finishing operations.

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Shaft Angle Digitizer Needs No Brushes

C. J. WAYMAN
The General Electric Co. Ltd.
England

Most shaft angle encoders tend to be bulky and complex or possess trouble-prone sliding contacts. Photoelectric devices are often environment-sensitive. A new approach is the induction digitizer. Inductive coupling eliminates contact problems and increases reliability. Single digitizer accuracies can be extended by coupling additional units.

Basically the device is a transformer with a single exciting winding and a number of secondaries equivalent to the number of binary digits required. These secondaries are wound around the teeth of a stator in a unique pattern to conform to the requirements of any suitable cyclic code. A single element ferromagnetic rotor, wide enough to embrace only one stator tooth, completes the magnetic circuit. Figure 1 shows a model of a 32-tooth digitizer with its secondary windings arranged for cyclic binary code.

Positioning the rotor at the desired shaft angle completes a particular magnetic circuit through one of the stator teeth. The windings pass in different directions through a particular stator gap depending on the coding used, thus setting up the coded pattern of output polarities for each shaft position. An output voltage similar in waveform to the excitation is induced in each of the digit windings with a polarity determined by the direction of winding at each stator tooth. The polarity at the output terminals of each winding determines whether the appropriate digit is 1 or 0.

A production form of the 32-tooth digitizer fits within a standard Size 11 synchro casing, gives a five-bit cyclic binary output, and requires 1 watt at 25 kc for excitation. For parallel readout, each of the five windings are connected to an amplifier and a phase detecting flip-flop. Sensitivity of the flip-flop is set at 50 mv, since the maximum output of the digitizer is about 0.5 volts rms. For serial readout, each of the digit windings are excited sequentially and the output taken from the "excitation" winding.

Accuracy can be increased by combining two or more digitizers in a coarse-fine measuring system. At high shaft speeds, interrupted gear mechanisms generate high amplitude acceleration torques on the coarse digitizer shaft. A simple circuit allows the use of simple gearing as coupling device by including an extra antiambiguity winding in the coarse digitizer to control the changeover of the more significant digits. Exciting this winding in phase with the main excitation winding broadens the angular range over which the coarse digitizer produces 0 outputs. Out-of-phase excitation broadens the angle for 1 outputs. In practice the antiambiguity winding is fed with the top digit output of the fine digitizer to determine whether the coarse output as a whole is odd or even. With this modification of excitation, plain gearing adequately ensures correct interpretation of position up to 12,000 rpm.

Figure 2 shows a two-digitizer geared system with a third digitizer shown dotted. The basic read blocks *B* comprise an amplifier, phase sensitive rectifier, and a flip-flop. Phase control of the antiambiguity winding on the coarse digitizer is via the *A* blocks reading a fine output.

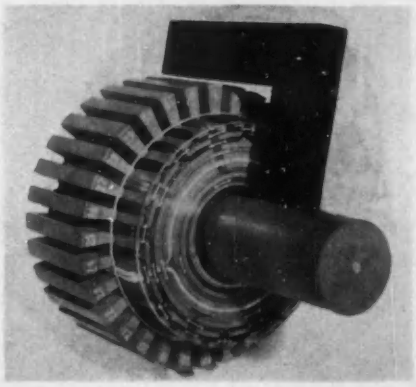
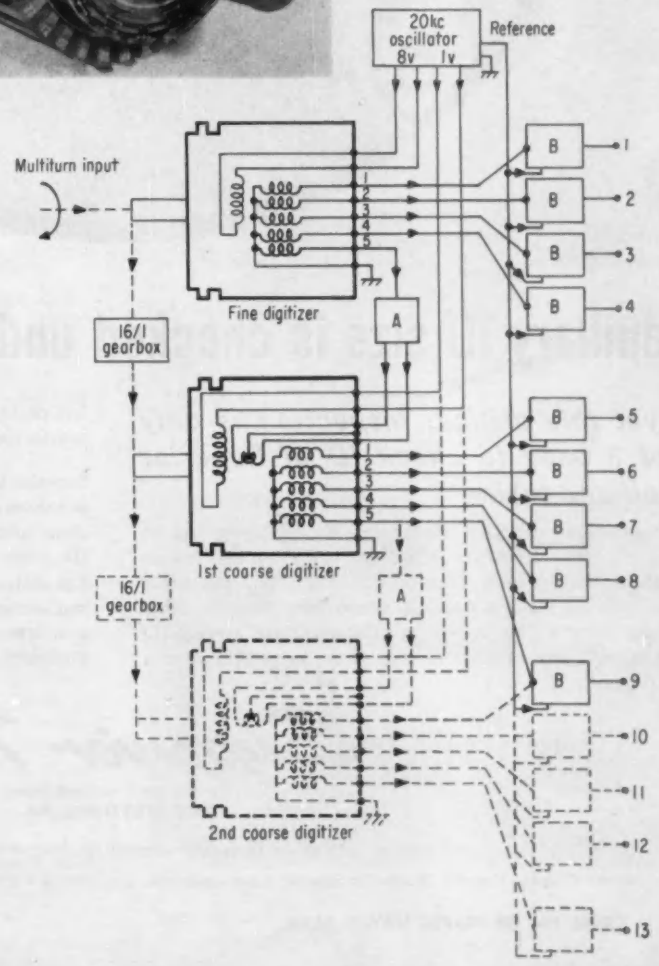
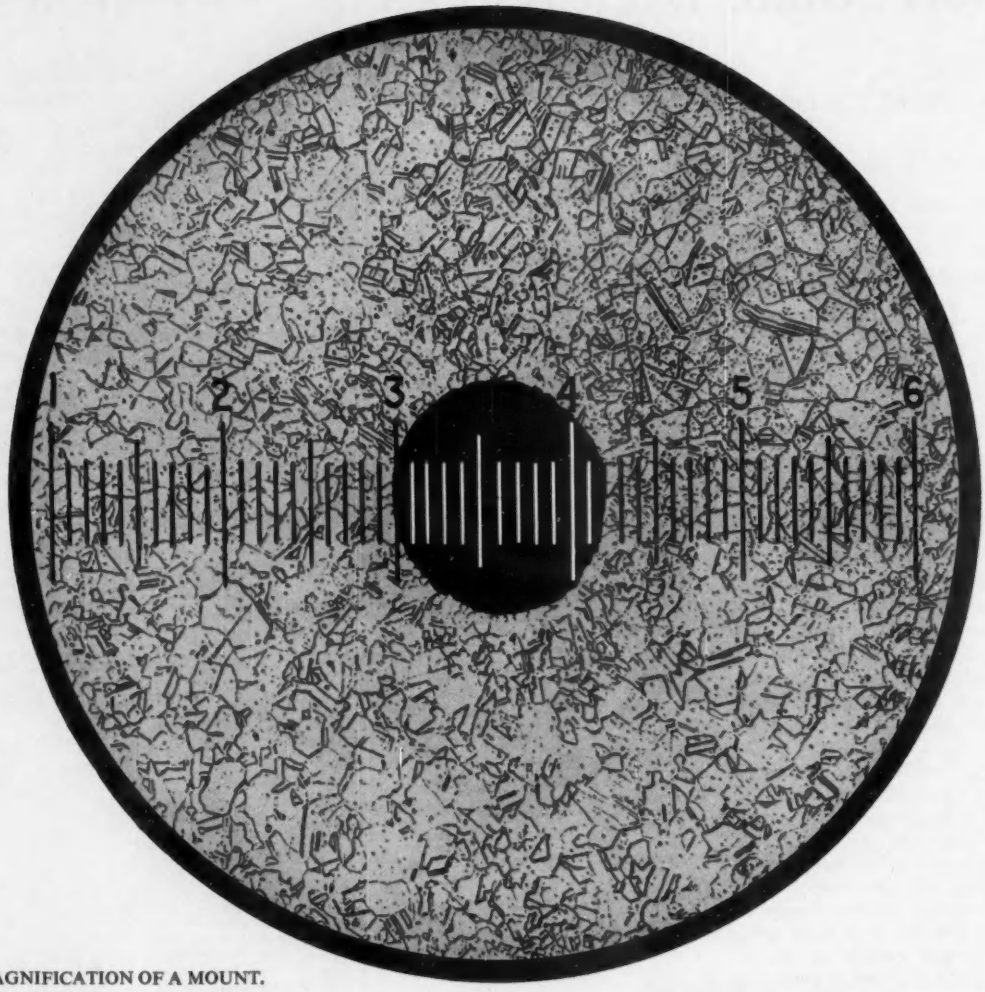


FIG. 1. Model shows the five binary digit winding pattern where direction of winding through each stator gap corresponds to code in use. Innermost winding is for excitation.

FIG. 2. Adding antiambiguity windings in the coarse digitizers permits simple gearing of units for more accuracy.





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NEW PRODUCTS

HOT-GAS GYRO suits short range missiles.

Ideal as a reference instrument for short range missiles, drones, and target vehicles, this newly developed gas-driven displacement gyro contains only four moving parts. Dubbed the Genie by its designers, the unit can outperform any other gas or spring-driven gyro and offers a degree of reliability unattainable even in electrical gyros. On top of this the maker claims that it can be produced at a fraction of the cost of conventional gyros and that small quantity deliveries can be made immediately. Stripped of all nonessentials, the Genie has fewer than 40 parts, or about half as many as are used in a conventional free gyro.

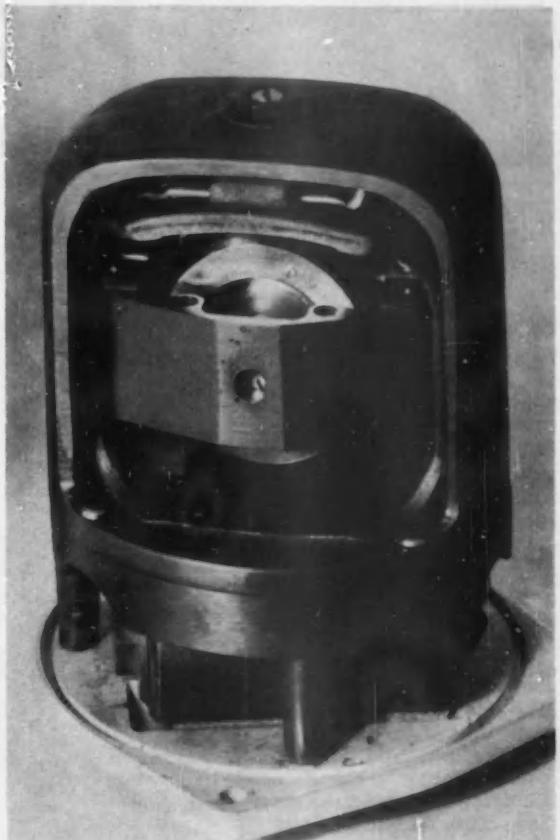
Its hot-gas drive, powerful yet inexpensive, is more than adequate for short duration missions. At the start of a mission, a solid or liquid propellant accelerates the gyro to high speed and the gyro automatically uncages. Time required for this is less than 0.1 sec. In flight the gyro operates in a coast-down mode for the duration of the mission. Its high average angular momentum (about 1.25 million gm-cm^2 per sec) provides usable stabilization for several minutes. Unit is designed for a drift rate of from 2 to 4 deg per min under extreme missile environments.

With a solid propellant charge which is impervious to deterioration or fatigue, the Genie can be stored indefinitely without threat of impaired reliability.

Aside from the firing squib, the gyro's only electrical elements are pickoffs. While the initial version uses commutator switch pickoffs, the unit can readily be adapted to use either potentiometer or magnetic pickoffs.

Its ability to meet performance requirements was unimpaired by environmental tests involving 100 g's shock, 9 g's vibration, 30 g's acceleration, and severe thermal shocks.—Lear, Inc. Grand Rapids, Mich.

Circle No. 309 on reply card

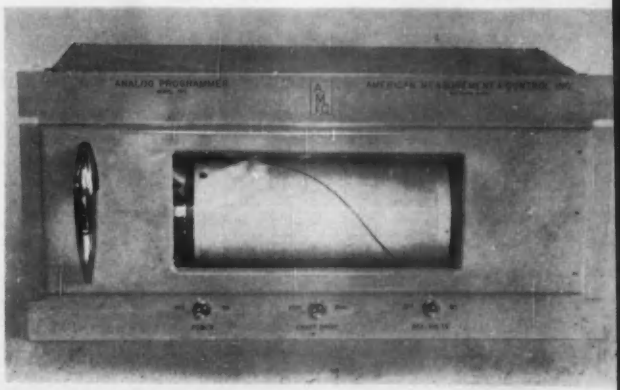


NEW ANALOG PROGRAMMER generates graph-drawn functions.

Photo at right shows the Model 750 analog programmer, an arbitrary function generator in which any single valued function (Y) drawn on graph paper with conductive ink is converted to a proportional voltage as a function of time (X). Has a response time of less than 10 microsec.

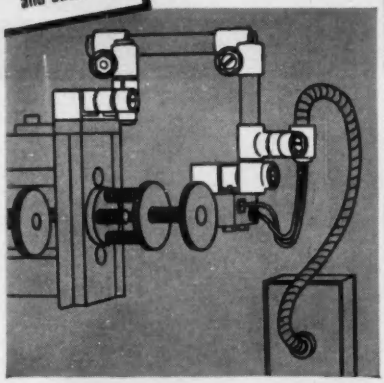
Basically it consists of a chart-supporting drum, a resistive roller or potentiometer, and two contact rollers. A synchronous motor working through a gear train provides the driving force. With a servomotor drive, drum position can be made a function of some independent variable.—American Measurement & Control, Inc., Waltham, Mass.

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Toothed faces of paired assemblers form rigid joints at every 10-degree increment, including right angles. Tight, all-around grip never burrs, scores, or distorts round stock—won't squeeze tubing out of shape. Only a screwdriver or a coin is needed to tighten the screw in the nesting nut.

Snap-clamp snaps on over existing structures and fittings. No need to take apart existing assemblies to make additions.

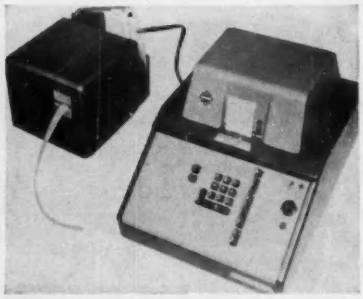
Sample offer—Your request on your letterhead will bring you a sample kit of **Rotocon** assemblers, free and postpaid. You have to see them, hold them in your hand, and experiment with them in your own application situations to discover the time and money they can save you.



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NEW PRODUCTS

DATA HANDLING & DISPLAY



TAPE ON THE SIDE

Performing routine adding machine computations with this combination yields a 5, 6, 7, or 8-channel punched paper tape in addition to the regular printed figures. Faster analysis of business data is thus possible with little more effort than in operating a standard adding machine. Speed of the punch is 20 characters per sec. Variable field control allows selection of the columns to be punched. Price of the two units: approximately $2,000.—Victor Adding Machine Co., Chicago, Ill.

Circle No. 311 on reply card



PAPER TO MAGNETIC TAPE

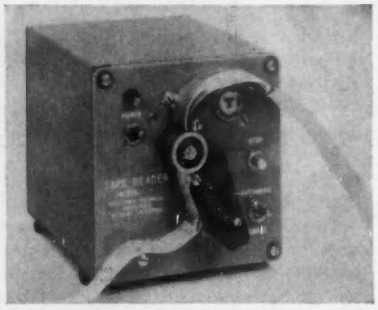
Conversion of paper tape to magnetic tape in the IBM 704 or 705 format is performed by the new Model ZA-26965 data translator. It accepts 5, 6, 7, or 8-level chad or chadless paper tapes in any code form. Output for entry into other computers can also be arranged. The unit is 74 in. high, 48 in. wide (including tape transport), and 24 in. deep. Input reading takes place at 300 characters per sec for perforated tape, 20 characters per sec for partially perforated tape. Price: $49,500—Electronic Engineering Co., Santa Ana, Calif.

Circle No. 312 on reply card

SPLIT-SECOND TIMING

A new time-speed recorder is said to be the only instrument of its type for monitoring automatic operations that provides split-second timing along with time-of-day information. Time markings along the edge of the chart show time of day any event occurs; pen sweep displays duration of the event. Standard chart speeds of ¾, 1½, 3, 6, and 12 in. per hour and per min are provided. Sweep time scale ranges from 1 sec to 1 hr are offered. Price is $975 with accessories.—R. B. Annis Co., Indianapolis, Ind.

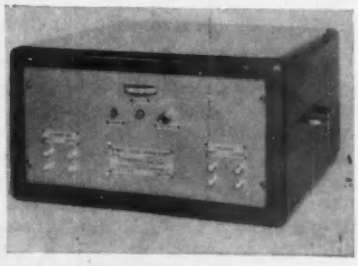
Circle No. 313 on reply card



LOWEST PRICE

This new single line tape reader is said to have the advantages of a high performance reader at the lowest price of any single line reader on the market. It is designed to operate single line or continuous run from an external trigger source and can accommodate 5, 6, 7, or 8-hole, 1-in. paper Mylar tape. Speed is 60 lines or characters per sec self-stepping or 50 lines per sec impulse stepping. Price: $235—California Technical Industries Div., Textron, Inc., Belmont, Calif.

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TRANSCEIVES DATA

This new high speed binary data transceiver allows computers to "talk"



...with the most basic tools at an engineer's disposal: experience, a drawing board, and a complete catalog of instruments and controls designed for the automated process. That's why you'll find more and more design engineers coming to depend on the new General Controls *Automation Controls Catalog*. Here is a "working" catalog for the shirt-sleeves engineer, because it puts a complete diversified line of controls for automation in a single usable format. When you get yours, scan through it quickly. You'll find everything you need for that next job — program timers, actuators, automatic valves, sensing devices, potentiometers, and counters. There is also an experienced staff of field engineers ready to lend a hand when you need it. Send for your copy of this new catalog now.

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EXCITATION: To 115 VRMS, 50 to 20,000 CPS
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MAXIMUM STROKE TO LENGTH RATIOS
DIFFERENTIAL TRANSFORMER SUPERIORITY & RELIABILITY
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to each other over commercial telephone lines at a rate of 2,400 bits per sec. All solid state, the device achieves its high speed through a unique modulation method which minimizes errors due to impulse noise, phase distortion, frequency translation, and other transmission problems. Inputs accepted may be either polar or impulse type of binary information. —Stromberg-Carlson Div., General Dynamics Corp., Rochester, N. Y.

Circle No. 315 on reply card

PLUS . . .

(316) Precise integrating of flows representable by a dc signal is offered by the new **electrical integrator** available from **GPE Controls, Inc.**, Chicago, Ill. . . . (317) **Waltham Precision Instrument Co.**, Waltham, Mass. has placed into production a new subminiature **elapsed time indicator** featuring digital readout. . . . (318) A new line of inkless **strip chart recorders** intended for utility systems by **General Electric Co.**, Schenectady, N. Y. eliminates unimportant momentary transients while charting power changes. . . . (319) Wide band, multichannel, magnetic tape recording under rugged environmental conditions is possible with a new **miniature recorder** from **Pacific Electro Magnetics Co.**, Palo Alto, Calif.

Circle No. 316, 317, 318, or 319 on reply card

RESEARCH, TEST & DEVELOPMENT

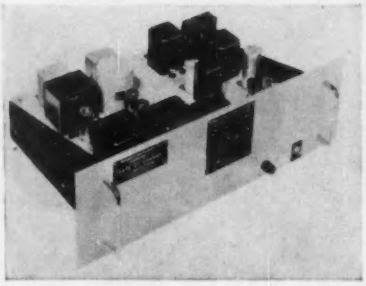


SYNCHRO REFERENCE

Functional accuracy of 2 sec of arc is the feature of a newly announced synchro standard for use as a testing reference and control. It eliminates the need for using a null detector and

a control transmitter mounted in an index stand. Used for control systems the standard serves as an accurate feed forward control device for machine tools, simulators, etc. Circuitry is all solid state in modular form.—Astrosystems, Inc., New York, N. Y.

Circle No. 320 on reply card



MEASURES CHANGES

A new self-contained rate-of-change computer can measure temperature changes directly from thermocouples, pressure changes from strain gages or resistance bulbs, Neutron flux buildup in reactors, and it can measure and control pH variations in various processes. The computer accepts dc signals, has high sensitivity, and may be connected in parallel with other transducers or recorders without loading them. It will drive strip chart recorders directly. No drift is experienced for the Model 0557-1, which is priced at $950.—Magnetic Instruments Co., Thornwood, N. Y.

Circle No. 321 on reply card

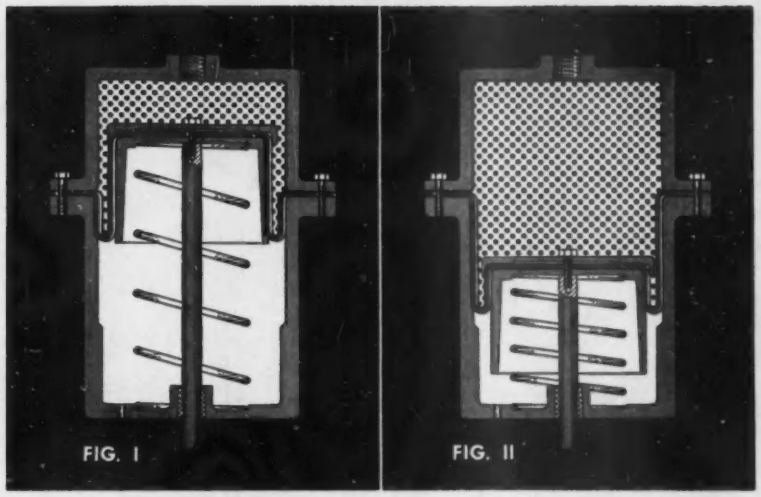
ALL SOLID STATE

Continuous real time solutions for mathematical computations and real time control of variables in the process industry are available with the CM-3, a new solid state analog computer. The single cabinet of the computer contains up to 12 ampilfiers, although there is no electronic limit to the number of amplifiers that can be used. Two or more CM-3's can be interconnected.—Southwestern Industrial Electronics Co., Div. Dresser Industries, Inc., Houston, Tex.

Circle No. 322 on reply card

SEQUENTIAL REITERATIVE

DYSTAC, a new analog computer, permits complex sequential reiterative calculations which once defied such machines. Only 1 min is needed to get a solution for any set of specifications with accuracy within ± 0.05 percent. The device features high speed



For Hydraulic and Pneumatic Applications

Nothing rolls like a Bellofram® Rolling Diaphragm. It's frictionless!

The Bellofram Rolling Diaphragm provides ultrasensitive response in hydraulic or pneumatic devices where frictionless, long-stroke action in small-diameter configurations is required . . . and where flex life of millions of cycles is necessary.

These desiderata are achieved through the *rolling* action of a flexible thin-sidewall diaphragm consisting of a high-tenacity fabric overlay embedded in elastomeric material.

Fig. I shows how Bellofram Rolling Diaphragm conforms to the piston. Fig. II shows how, as the piston descends under pressure, the diaphragm *rolls* off the piston's sidewall and onto the cylinder's sidewall in a smooth, continuous, frictionless movement.

The Bellofram principle can be applied widely in actuators, pumps, instruments, seals, accumulators, fluid dampers, etc.

Which of these advantages are you looking for?

To the designer confronted with situations for which conventional bellows, O-rings, or cup packings are inadequate, Bellofram Rolling Diaphragm offers a constellation of advantages found in no other product:

1. Friction-free (low hysteresis).
2. No break-out friction effects.
3. Completely leakproof device.
4. Constant area in all piston positions.
5. Almost infinite flex life (millions of cycles).
6. Sensitivity to extremely small pressure changes.
7. No mechanical spring gradient.
8. Compatibility with practically all environmental gases or fluids.
9. Automatic de-icing action.
10. Free positioning with complete relaxation at any point in its stroke.
11. Does not require close machine finish tolerances on pistons and cylinders.
12. Freedom from abrasive wear.
13. One hundred stock sizes. Four mounting configurations. Special types and sizes designed to order.
14. Excellent temperature stability, from —85°F. to 550°F. (from —120°F. to 700°F. in some cases).

Wide range of working pressures: 1 in. H_2O to 500 psi (up to 1200 psi in some cases).

Effective pressure areas from .028 to 108 sq. in.

Cylinder bore diameters from .25 to 12 in.

Extended range of stroke (.01 to 12 in.).

Send for Free Literature

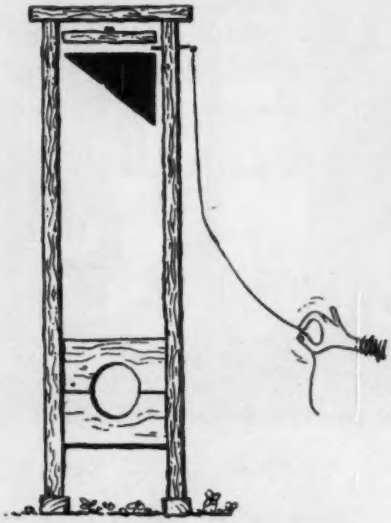
Some territories open for technical sales representatives.

Bellofram®

®Reg. trademark U.S.A. and foreign countries • Bellofram Rolling Diaphragms are protected by U.S.A. and foreign patents.

BELLOFRAM CORPORATION, 38 BLANCHARD ROAD, BURLINGTON, MASSACHUSETTS

BRowning 2-2100 Mission 3-9000

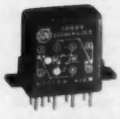


SIGMA

CAN NOW TAKE CARE OF COMPETITION IN ON-OFF DEVICES

The Great Competitive Game being what it is, drastic measures are often necessary if a new product is to be assured of success. Frequently, one must even resort to publishing better specs than the competitor has announced, and then build a product to meet them. Some companies even go so far as to reverse the order of these events but the procedure is rare in North America.

We used to say the Sigma Series 33 was a sliding current relay and that it would work on 200 milliwatts. Now there is evidence to the contrary: (1) the "33" works best when *abruptly* energized, and (2) there's a new adjustment coded "VG" that needs only *100 mw* for operation. (How's that for being wrong two out of two?)



Series 33 relay

This new subminiature competitor (on the left, next to Dr. Guillotin)

stays within spec and won't open its contacts, energized or not, at 30 g to 5000 cycles, under 70 g shocks, and over a −65°C. to +125°C. temperature range. Contact form is DPDT, polarized, magnetically biased. This is designated "Form Y" by us and means that the armature occupies one closed position when there is no coil signal, the other closed position when a signal of correct polarity and magnitude is applied, and back to the first position when the signal is removed. On special order, 33VG's can be supplied with dual coils and/or gold alloy contacts for dry circuit work.

One other thing about applications: the VG adjustment of the 33 is good for either on-off or off-on requirements; order device in main illustration only if your application is the former. Series 33 Bulletin and VG supplement on request.

At WESCON—Booth 749-750

SIGMA

SIGMA INSTRUMENTS, INC.

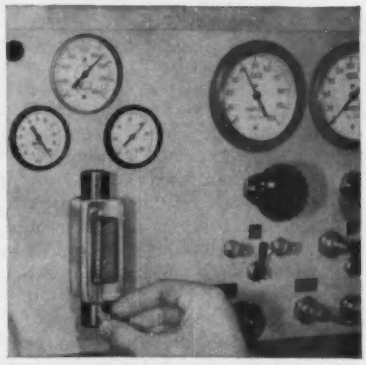
69 Pearl St., So. Braintree 85, Mass.

An Affiliate of The Fisher-Pierce Co. (since 1939)

NEW PRODUCTS

repetitive operation and dynamic memory. Only 44 amplifiers are needed in this design for a four-component problem. Basic machine is available with 46 amplifiers, field-expandable to 70 operational amplifiers. Larger systems are equipped with 222 operational amplifiers, 90 electronic multipliers, and 30 10-segment diode function generators. Frequency response is adequate for 60 solutions per sec. — Computer Systems, Inc., New York, N. Y.

Circle No. 323 on reply card



MINIATURE FLOWMETER

Specifically designed for measurement of low flow rates of either liquids or gases, the Minirator is an inexpensive, miniature flowmeter that has many of the design features of full size models. Superior readability and accuracy are claimed. The tube of the unit is of the snap-in type, permitting a change in range in a few seconds without tools. End fittings rotate through 360 deg for ease in mounting, and the meter is designed to be flush or surface mounted on a panel or installed in line. It is suitable for either analytical or normal process use.—Fisher & Porter Co., Warminster, Pa.

Circle No. 324 on reply card

IMPROVED COMPUTER

New improvements in the design of the company's analog computer, which features an operating bandwidth at least 100 times wider than the present commercial specifications, include instantaneous overload indication and recovery. This permits repetitive operation of overloading solutions without amplifier "hang up" and study of normally divergent solutions.



Teletype manufactures for continuous performance

Continuous performance is traditional with Teletype message and data communications equipment. For example, a Teletype Model 28 printer—test-run on a round-the-clock basis at 100 words per minute—operated continuously, hour after hour, for a total of 1,500 hours, printed 9,000,000 words! At the end of this exhaustive test, the machine was still functioning smoothly and steadily.

In maintaining its tradition of quality, Teletype's manufacturing methods play a major role. Specialized machine tools, like the jig grinder shown above, selective heat-treating processes, electronic measuring devices—these are part of a manufacturing technique that insures consistent quality.

When you select Teletype equipment, you can be sure of dependable, trouble-free performance. Teletype Corporation manufactures this equipment for the Bell System and others who require the utmost reliability from their data communications systems.



Typing Tape Punch



Tape Reader



Send-Receive Page Printer



Automatic Send-Receive Set

FREE Model 28 line folder. Write Dept. 26-H
5555 Touhy Avenue, Skokie, Illinois.

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

See Teletype Corporation's equipment exhibit at the Western Electronic Show & Convention, August 23-26, Los Angeles, California.

CIRCLE 153 ON READER SERVICE CARD



Pressure switches that only turn on warning lights in uncontaminated air find it tough going in such a simple thing as salt air atmospheres.

The way you beat this problem is to check the pressure switch under every known operating requirement . . . not just in a vacuum, or 0% humidity or just at sea level, for instance.

Take Model 6621 shown at right that can do so many jobs . . . operate warning lights, measure fuel and oil pressures, actuate air-conditioning for electronic gear. This model, in ranges from 5 to 1000 psig, operates between −65 to 275°F, withstands shock up to 100 g's and vibration to 2000 cps. It is only 1 1/16" diameter by 2½" and weighs but two ounces.

Copy us. Test it yourself for six weeks under all the requirements of your job.

Or save six weeks by checking our own test data on a full line of pressure switches for the type that meets your needs best. Call Mr. Charles Colt at Consolidated Controls, Bethel, Conn. Phone Pioneer 3-6721, DDD Code 203.



Inches of Water to Hundreds of Atmospheres

Model 6621 shown above is one of more than 300 pressure switches available from Consolidated Controls for missile, aircraft and nuclear applications. Working pressures range from 10" of water to 10,000 psi at ambient temperatures from −65°F to 1000°F. Standard models for

- high vibration
- differential pressures
- hydraulic
- miniaturized applications
- high temperature

CONSOLIDATED CONTROLS CORPORATION

A Member of The Condec Group

BETHEL, CONNECTICUT
INGLEWOOD, CALIFORNIA

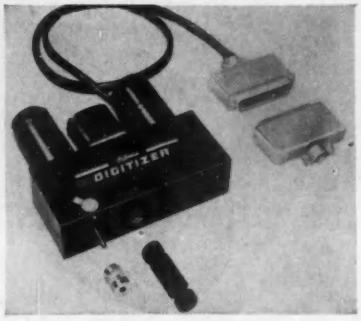
154 CIRCLE 154 ON READER SERVICE CARD

NEW PRODUCTS

The new design applies all forcing functions and initial conditions electronically, eliminating the dependence on travel time of electromechanical devices. All inputs are now automatically grounded when not in use for additional gain and bandwith stability. Chopper stabilization of nonlinear components for application throughout the high and low speed computation ranges is now offered. The need for various load corrections is eliminated by the component inputs' presenting identical load impedances.–GPS Instrument Co., Inc., Newton, Mass.

Circle No. 325 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



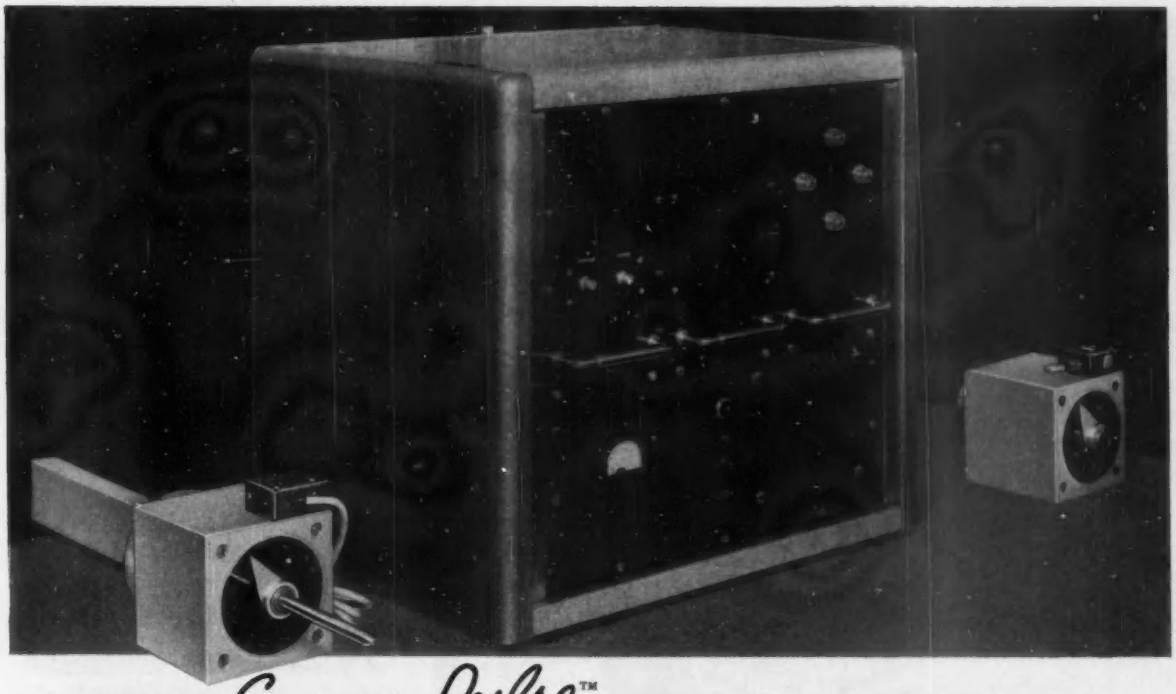
CONTINUOUS OR ON-DEMAND

This nonambiguous electromechanical shaft position encoder provides straight decimal contact closure output. The digitizer features continuous or on-demand readout and has slewing speeds up to 3,000 counts per sec. Resolution can be selected from 10 to 1,000 counts per rev. The device has high current capacity and low input torque and will operate parallel entry printers and lampbanks directly.–Coleman Electronics, Inc., Gardena, Calif.

Circle No. 326 on reply card

MEETS TIGHT SPECS

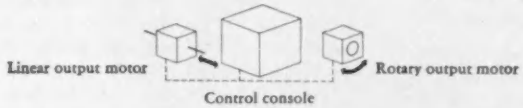
Designed to meet the exacting requirements of telemetry and control work in missiles, new pressure potentiometers measure less than an inch in diameter and are 2 in. long; they weigh 3½ oz including pressure and



NEW *Syncro-Pulse*™ STEP MOTOR...

STEP MOTOR	Size:	5″ x 5″ (Square) x 7″ long (not including output shaft). Mounting lugs or feet can be furnished to suit application.
	Torque:	Positive starting, stepping, and stopping up to 100 steps per second with 80 inch oz. applied load; up to 200 steps per second with 40 inch oz. applied load. Static break-away torque 200 inch oz.
POWER SUPPLY—CONTROL SYSTEMS	Size:	21″ high x 22″ wide x 18″ deep. Modular plug in basic units and circuit boards. Can also be furnished with standard 19″ panel mounts.
	Input Power:	120 volts 60 cycle or 220/440 volt 3 phase 60 cycle. Features regulated DC supply for control circuitry and 40 volt for step motor power.
	Accessories:	Variable frequency pulse generator and/or manual preset counter for gating pulse input to step motor control. Transistorized preamps for pulse signals as low as .0004 volts peak.

Note: *Other sizes and types of step motors suitable for instrumentation and airborne applications are available as small as size 11.*



REVERSIBLE...EXACT RESPONSE

GREATEST TORQUE CAPABILITIES...

200 steps per second with 40 inch oz. applied load

▶ Exceptional dynamic characteristics are found in the new Farnham Syncro-Pulse™ Step Motor. Two hundred steps per revolution assure high resolution and linear accuracy. Without feedback circuitry, clutches, or brakes, the motor provides mechanical motion, positioning actuation, digital-to-analog conversion, or counting as an *exact* function of pulse signals.

The Farnham Syncro-Pulse™ Step Motor is furnished complete with combination DC power supply and solid-state, completely transistorized control circuit. There are separate inputs for "forward" and "reverse" pulse signals. Input circuits will accept sine wave, square wave, or triggered pulses as low as 6 volts peak. Input impedance is 1000 ohms.

Positive starting, stepping, and stopping at pulse frequencies up to 300 pulses per second are possible with this motor. It will operate at 4000 pulses per second with nominal controlled acceleration and deceleration of pulse signal source. Step motor remains "locked" during dwell periods in pulse signal source. Available with either rotary output shaft or non-rotating coaxial lead screw. Calibrated face plate dial and pointer indicates stepped position of armature.

FARNHAM *Electronics* DIVISION

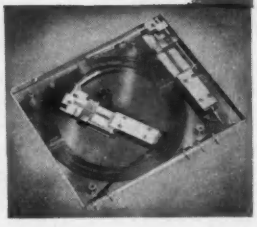
WIESNER-RAPP CO., INC.
1600 SENECA ST., BUFFALO 10, N. Y.

CIRCLE 155 ON READER SERVICE CARD 155



No moving parts in

FERRANTI
Magnetostriction Delay Lines



Ferranti engineers have a depth of experience unmatched in this specialty.
We can provide stock units that have been proved in performance — or custom design to your special applications.

Features that characterize Ferranti Delay Lines:
Temperature stable . . . wide temperature operating range . . . High digit rates up to 1 Mc/s for delays up to 3 milliseconds . . . Small size, light weight . . . No moving parts . . . Low cost, highly reliable elements for delay, storage and correlation — fixed and variable.

Write for detailed literature

FERRANTI

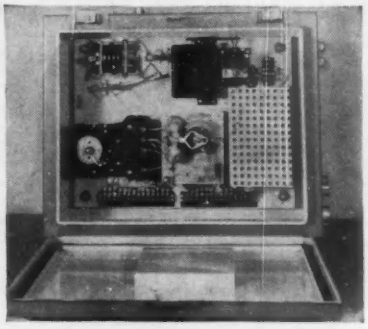
FERRANTI ELECTRIC, INC.
ELECTRONICS DIVISION
95 MADISON AVENUE HEMPSTEAD, N. Y.

156 CIRCLE 156 ON READER SERVICE CARD

NEW PRODUCTS

electrical connectors. Units are available in eight ranges from 0-500 to 0-5,000 psia. Up to 75-volt output full scale may be obtained without amplification. – Trans-Sonics, Inc., Burlington, Mass.

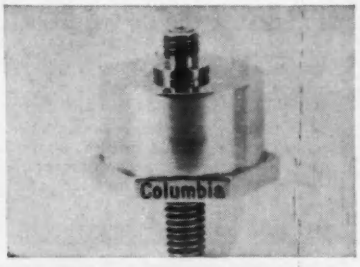
Circle No. 327 on reply card



MECHANICALLY AMPLIFIED

A new series of digital transducers for pressure, flow, temperature, or other variables uses mechanical scans to provide digital output in the form of contact closures for data recording or transmission. Mechanical amplifiers drive shaft position encoders from Bourdon tubes, bellows, diaphragms, etc. A small electric motor provides drive power for the unit. Options include a deviation or upset alarm. Explosion-proof models are available. –Datex Corp., Monrovia, Calif.

Circle No. 328 on reply card



SENSITIVE AT LOW LEVELS

Intended for low level g measurements, this new accelerometer has a sensitivity of 100 milivolts per g. A special case design permits use of the device in high intensity noise fields to 160 db and in other nonvibrational environments with minimum spurious response. Maximum acceleration is 10,000 g; frequency response is from 1 cps to 3 kcps. Resonant frequency is at 55 dc with amplitude linearity

LIKE **WORDS** IN A SENTENCE...

CUBIC DIGITAL SYSTEMS

SPEAK FOR THEMSELVES!



Standard-size Cubic Digital Instruments, with modular construction of plug-in units, make for easy development of sophisticated digital systems from standard off-the-shelf instruments. Wiring of systems is between *cases*, and the release of front-panel locking knobs permits the unit to slide out. Simple or complex systems for measurement and recording are quickly, easily available from Cubic, offering "digital systems that design themselves."

And, of course, Cubic quality speaks for itself, too, with such unique features as "controlled drive" stepping switches which swing up and out for ease of routine maintenance. From front panel to rear connector panel, Cubic's is *the superior* digital instrument.

NEW FROM CUBIC . . . the Talking Meter, instrumentation that really *does* speak for itself, with measurements or other parameters reported to the ear by a clear human voice.

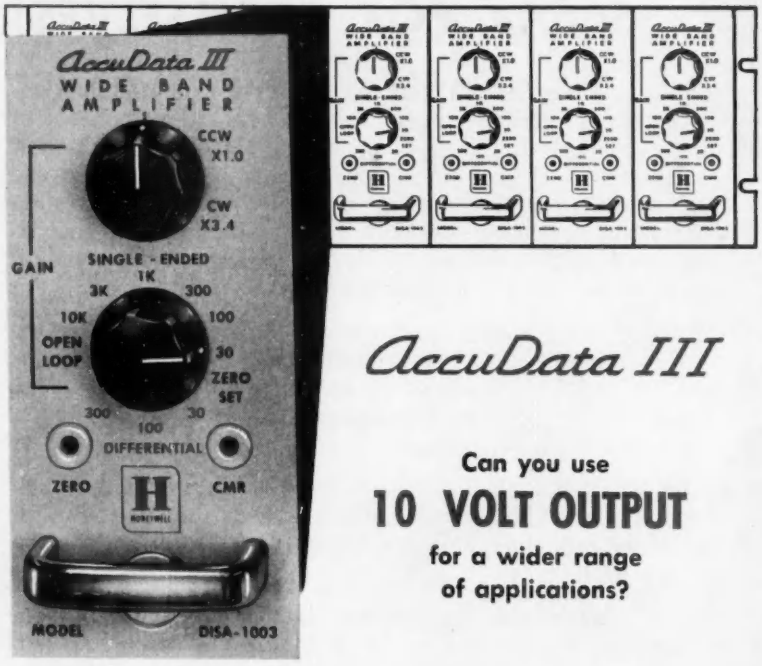
Years-ahead engineering, factory production techniques inspired by pride in the end result, careful quality control and reliability testing . . . all these factors make Cubic's the truly fine instrumentation . . . Digital Systems that speak for themselves.

CUBIC CORPORATION
INDUSTRIAL DIVISION
5575 Kearny Villa Road, San Diego 11, California
Electronic Engineering With a Dimension for the Future

CIRCLE 157 ON READER SERVICE CARD 157

from Honeywell... ANOTHER DIAMOND JUBILEE PRODUCT

NEW! WIDE-BAND D-C AMPLIFIER



AccuData III

Can you use

10 VOLT OUTPUT

for a wider range of applications?

In the new all-transistor AccuData III, low level signals from a wide variety of transducers can be amplified up to 10 volts with a high degree of accuracy. At 30 mv full scale input the noise error (0-10 cps) is less than 0.007%; common mode voltage transients are less than 0.008%; and zero drift is less than 0.007%. The total error, therefore, is only 0.022% . . . a new level of accuracy.

The Honeywell AccuData III Amplifier is particularly useful in high accuracy data handling systems where pick-up problems associated with long cable runs and ground loops must be completely eliminated.

The high 10 volt output allows direct connection between transducer and a wide selection of output devices including:

Analog/Digital Converters
High Speed Oscillographs
High Speed Printers
Servo Control Valves
High Speed Multiplexers
Telemeter Oscillator Controls

Either single ended or differential input ranges may be selected with a frequency range up to 20 kc. Input impedance is 20 megohms single-ended and 2 megohms differential. Seven amplifiers mounted in a 19 inch relay rack occupy a height of less than 5¼ inches. No cooling fans are required since the amplifier heat dissipation is only 8 watts.

Write for Bulletin BS DISA-3 to Minneapolis-Honeywell, Boston Division, Dept. 84, 40 Life Street, Boston 35, Massachusetts.

Honeywell

75th YEAR PIONEERING THE FUTURE

Industrial Products Group SINCE 1885

NEW PRODUCTS

within ±1 percent. Case is a ¾-in. stainless steel hexagon 0.45 in. high. The unit weighs only 23.5 gm. Single unit price is $160.—Columbia Research Labs., Woodlyne, Pa.

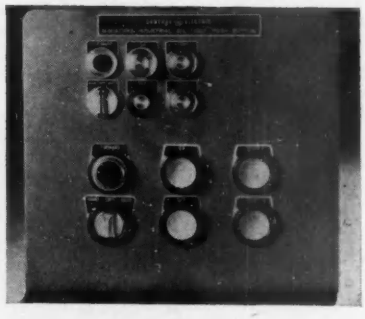
Circle No. 329 on reply card

PLUS . . .

(330) Only 1⅝ in. high, new **potentiometers** from **Carter Mfg. Corp.**, Hudson, Mass., feature a unique drum design which permits conformities to 0.1 percent for all resistance values . . . (331) **Three-axis accelerometer** with potentiometer output that weighs only ½ lb and is 2 in. long and 2½ in. in diam is available from **Humphrey, Inc.**, San Diego, Calif.

Circle No. 330 or 331 on reply card

CONTROLLERS, SWITCHES & RELAYS



SPACE REDUCERS

Demonstrated above is the substantial panel space reduction (at least 40 percent) made possible by a new, complete line of miniature, industrial, oil-tight pushbutton switch units. They may be mounted as close as 1¼ in. apart as contrasted with at least 2¼ in. for heavy duty types. The reduced size units still offer the operating and functional forms now available in the company's heavy duty line: pushbutton, illuminated mushroom-head buttons, transformer-type indicating lights, and push-to-test indicating lights. Besides applications to alleviate crowded panels of, say, numerically controlled machines, the new units can be used for graphic panels and computing-control systems

TESTS PROVE DOLLARS SAVED...

By new Instrument Record Marking System now installed at Mobil Oil Paulsboro Refinery

Controlled field tests by Mobil Oil Company engineers show *substantial* savings on meter recorder maintenance—with Esterbrook's new Meter Marking System on round chart recorders.

New! A *customized* Meter Marking System with easy "Slip-In" Cartridge

Custom-built by Esterbrook for the Paulsboro (N.J.) test site, Mobil's new Marking System replaces manually-filled, open-bucket type pen system with *modern ink-cartridge convenience*. Designed by Esterbrook's Technical Products Division, this system won't clog, won't flood or break down. *Result:* minimum maintenance.

Give your customers the benefit of ink cartridge convenience and a century of experience in the recording product you build...*Now*—Esterbrook's Technical Products and Instrument Division will custom-design and build a new marking system for any type recorder. Satisfaction guaranteed. For further information, write:

TECHNICAL PRODUCTS AND INSTRUMENT DIVISION

The Esterbrook Pen Company

Camden 1, New Jersey

NAME _____

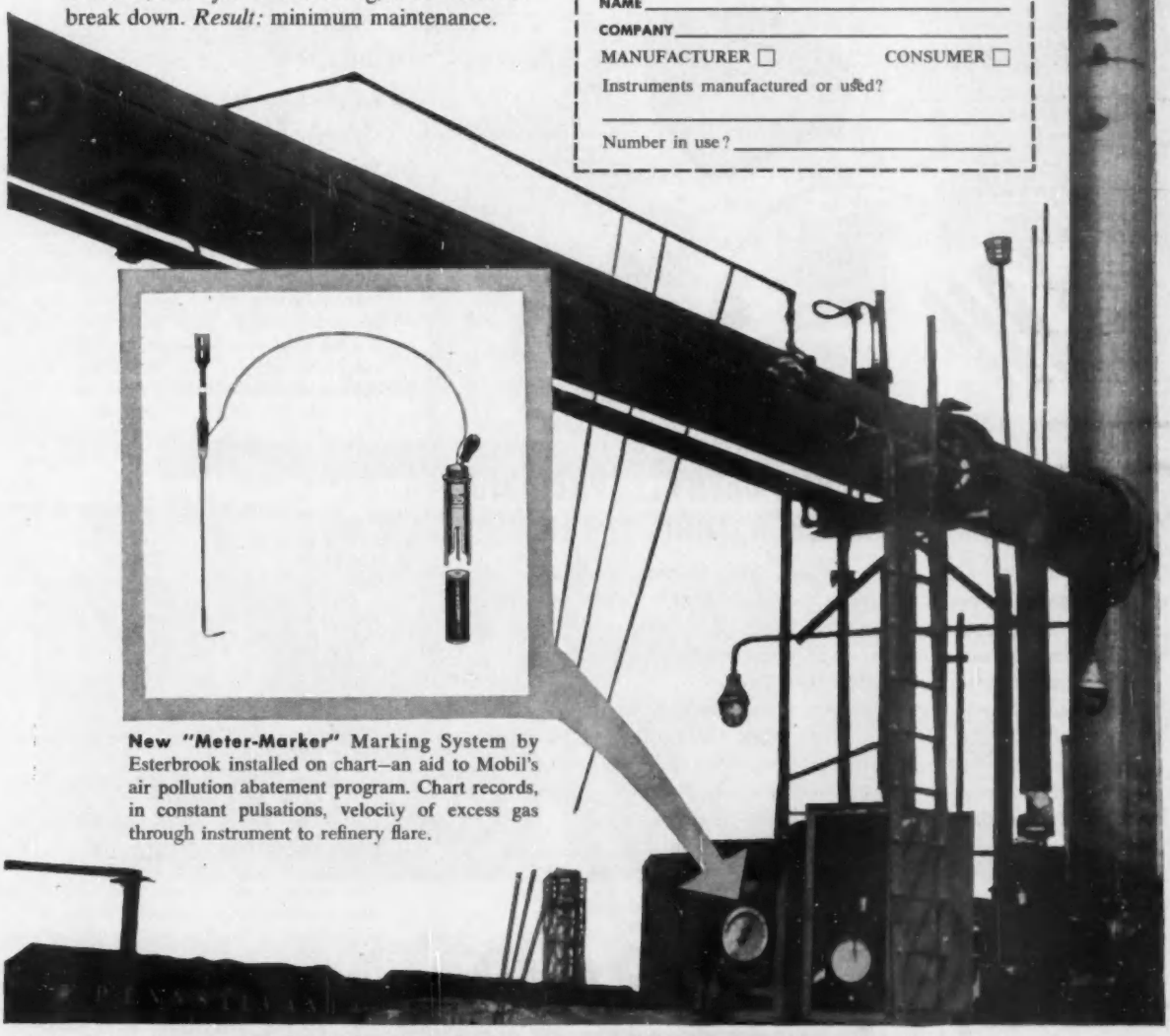
COMPANY _____

MANUFACTURER ☐ CONSUMER ☐

Instruments manufactured or used?

_____

Number in use? _____



New "Meter-Marker" Marking System by Esterbrook installed on chart—an aid to Mobil's air pollution abatement program. Chart records, in constant pulsations, velocity of excess gas through instrument to refinery flare.

Esterbrook Pen Company, Ltd., Birmingham 4, England • Esterbrook Pen Company of Canada, Ltd., Toronto, Ontario, Canada
Esterbrook Pen Company de Mexico, S.A. de C.V., Mexico, D.F., Mexico
Esterbrook, Industria de Canetas, Ltda., Rio de Janeiro, Brazil • Esterbrook Pen Company de Columbia, S.A., Bogota, Colombia

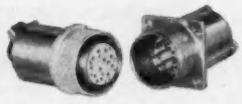
inventive accomplishment in temperature sensing

from HARCO...

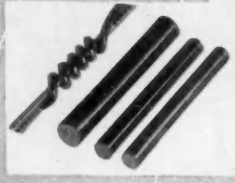
HARNESSES
complete line of standard parts and techniques to meet the exacting demands of modern thermocouple circuitry . . . standard or special applications. Bulletin 202.



CONNECTORS
accommodate greatest possible number of thermocouples in smallest space . . . yet have the mechanical strength and temperature resistance necessary to meet severe environmental conditions. Bulletin 185.

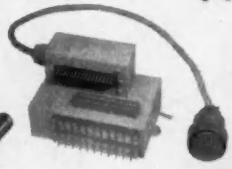


COMPLETE LINE OF METAL SHEATHED THERMOCOUPLES
especially for rapid, accurate, economical temperature sensing applications industry-wide. Accuracy of calibration well within recommended I.S.A. limits. Bulletin 161.





NEW CALIBRATION STAND
available in many models. Furnace design for acceptance of many different T/C configurations is available. Accuracy of readout within ±½°F. Bulletin 201.

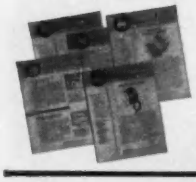


NEW T/C REFERENCE JUNCTION COMPENSATOR
completely eliminates need for conventional ice bath as reference temperature source in thermocouple calibration. Several models, all with fifteen channels. Bulletin 201.

THERMOCOUPLE THERMOMETRY... PRECISION DEVICES FOR TEMPERATURE SENSING

All HARCO equipment... thermocouples, special potentiometers, pulse dividers, extension leads, pressure probes, and the devices shown above... is subjected to rigorous quality-control and inspection procedures to ensure performance accuracy and reliability, in application after countless application.

Because of today's rapid advances in both equipment and process development, the number of different temperature problems is increasing greatly... as is the close degree of accuracy and certainty required in their solution... and there is HARCO equipment to assist the solution of any such problem, however unique.



For further information on any HARCO product mentioned, write for specific literature, or ask for the name of the HARCO representative near you. If no standard HARCO device suits your special needs, we'll design a special one for you. Inquire.

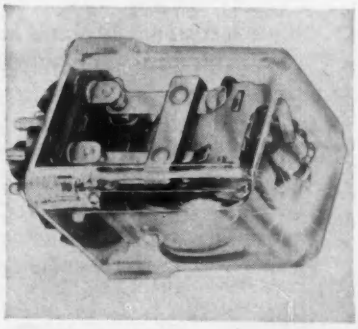
HARCO LABORATORIES *Inc.*

DEPT. CE • 77 OLIVE STREET • NEW HAVEN, CONNECTICUT

NEW PRODUCTS

in many other industries. New line meets applicable standards of NEMA, NMTBA, and JIC.—General Electric Co., Schenectady, N. Y.

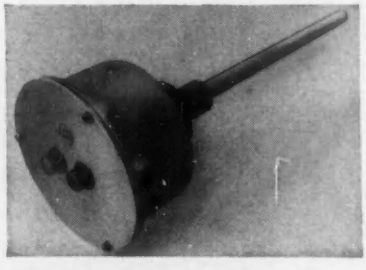
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LAMP'S BUILT IN

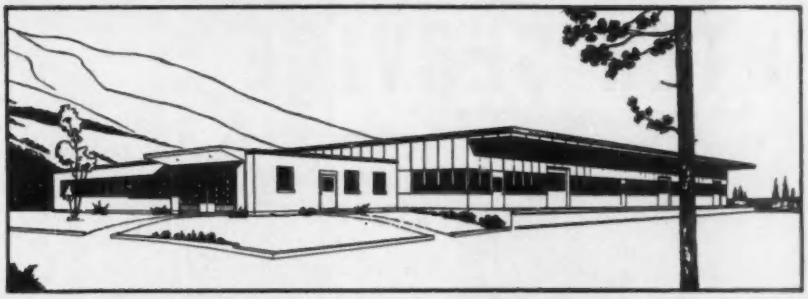
Featured as an aid to trouble shooting, a neon lamp is built into a new general purpose relay. The indicator is connected in series with a resistor, and both components are connected in parallel with the relay coil to provide a positive means of determining current availability. Silver cadmium contacts rated at 10 amp are standard for both ac and dc models. Silver 5-amp contacts are also available. Dc operation from 6 to 110 volts and ac operation from 6 to 230 volts are available.—Potter & Brumfield Div., American Machine & Foundry Corp., Princeton, Ind.

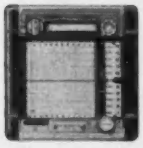
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CAPACITANCE OPERATED

Two versions of a transistorized capacitance relay have recently been announced: for direct mounting with the probe integral with the relay and a wall mounting-type with separate probe connected by a coaxial cable. The instrument housing is of aluminum alloy and is weatherproof. Electrical supply required is 110-120 or 200-240 vac, single phase, 50 cps. Ex-





NEW HOME FOR SWARTWOUT AUTRONIC® CONTROLS. INDUSTRY'S FIRST AND "OLDEST" FULLY ELECTRONIC CONTROL SYSTEMS NOW COME TO YOU FROM THE NEWEST INSTRUMENT PLANT IN THE COUNTRY. Expanded facilities. Improved manufacturing techniques. Computer-automated production and inventory control. These and other recently instituted efficiencies have pushed Autronic production to record levels in record time. Our field engineering staff has been enlarged, too. Service is better all the way around. Now, more than ever before, Swartwout is the leader in electronic process instrumentation.





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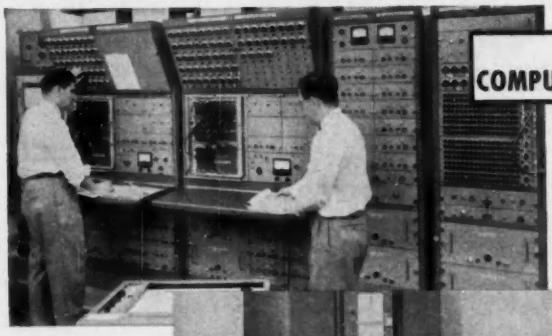
SWARTWOUT DIVISION, CRANE CO.

Hooksett Industrial Park, Manchester, New Hampshire

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for problems having complex equations where several dependent variables are involved. This method offers speed and flexibility as it performs all of its operations simultaneously, rather than in sequence.

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with unusual flexibility of programming schemes. Ideally suited to both repetitive and non-repetitive problems, regardless of complexity.



Take advantage of this experienced, versatile engineering staff to solve your engineering, research, manufacturing or production problems

Computer Center service is offered in three ways for your convenience: 1) Computer Center personnel to perform the entire analysis, programming, and solution of a given problem; 2) the client, when qualified, performs the analyses and programming, and operates the computer with staff personnel assisting as necessary; 3) center and client personnel form a team to work together in computer programming, operation and analysis of the results of the problem.

Land-Air, Inc. has computer programming and operation experience dating back to 1949, at which time the monitoring and measuring of missile performance at Pt. Mugu, California was contracted to Land-Air. Since that time, our staff engineers have participated in the solution of a wide variety of problems in many different types of industry. This experience is available to clients who do not have computing equipment available, who wish to gain experience with computing equipment, or who require additional personnel or computer time to supplement their own facilities. In all cases, it is the objective of the Land-Air Computing Center to apply creative efforts to obtain the best solution to problems, with positive results obtained with a minimum of computing and programming time.

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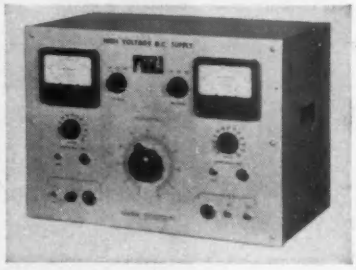
For further information and literature, phone UNderhill 7-7550 or write to:

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CHICAGO 31, ILLINOIS

cluding external alarm devices the power consumption is 3 watts. Sensitivity is better than 0.1 pf; stability error does not exceed 0.15 pf from mean value over six months with same supply voltage and temperature. Sealed triple-pole changeover contacts can switch 5 amps at 250 vac.—Bailey Meters & Controls Ltd., Croydon, England.

Circle No. 334 on reply card

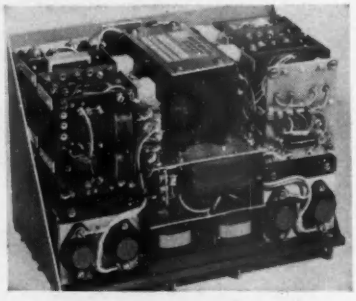
POWER SUPPLIES



PORTABLE POWER

Completely self-contained, this portable, instrumented, high voltage power supply has a dc output of 35 kv at 1 ma and 30 kv at 5 ma. The unit measures 12 x 14 x 12 in. deep and weighs 60 lb. Polarity may be reversed by changing a simple plug-in connection. Ripple factor is less than 0.5 percent ma rms. Meters are a three-range kilovolt meter and a three-range milliamp meter.—Del Electronics Corp., Mt. Vernon, N. Y.

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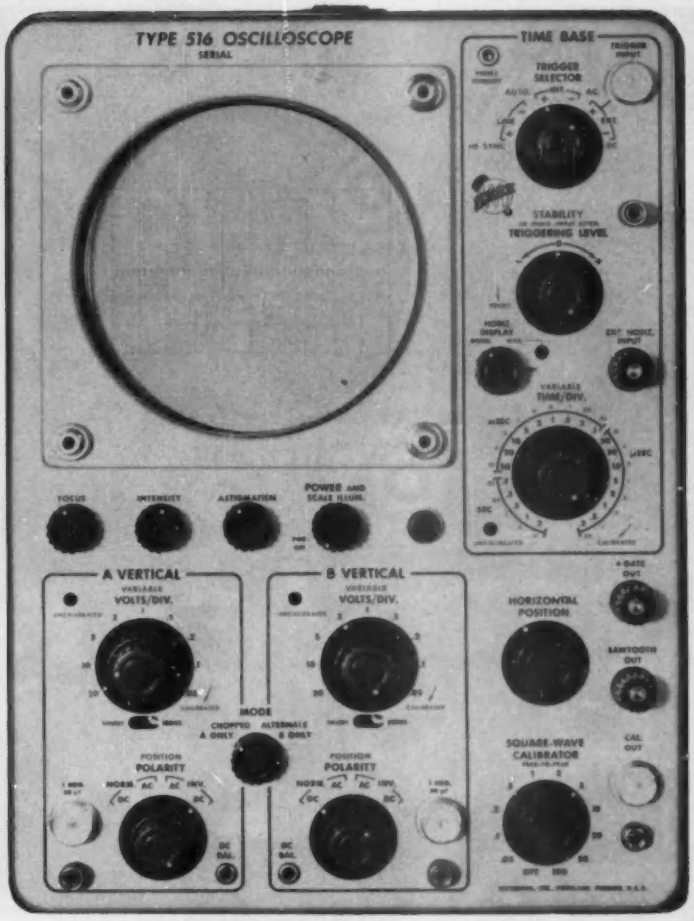


EFFICIENT INVERTER

All-static design is used in this new precision dc to ac power converter designed to operate from a nominal

NEW
DUAL-TRACE
DC-to-15 MC OSCILLOSCOPE

Tektronix Type 516



The vertical-deflection system of this new Dual-Trace Oscilloscope has four operating modes: (1) Input channels switched on alternate sweeps—(2) Input channels switched at a free-running rate of about 150 kc—(3) Channel A used separately—(4) Channel B used separately. It is a completely-integrated high-quality laboratory oscilloscope with the additional advantages of small size, low weight, high reliability, and easy operation.

Your Tektronix Field Engineer will be happy to arrange a demonstration in your application. Call him for complete details.



Main Characteristics

Frequency Response
dc to 15 mc.

Transient Response
Risetime—23 nanoseconds.

Vertical Sensitivity
0.05 v/div to 20 v/div in 9 calibrated steps.
Continuously variable from 0.05 v/div to approximately 50 v/div uncalibrated.

4 Operating Modes
Channel A only,
Channel B only,
Chopped—electronic switching at about 150 kc—with switching transients blanked,
Alternate—electronic switching on alternate sweeps.

Sweep Range
0.2 μsec/div to 2 sec/div in 22 calibrated steps.
Continuously variable from 0.04 μsec/div to 6 sec/div uncalibrated.
5-X magnification.

Trigger System
Automatic or amplitude-level selection (preset or manually set).
Rising or falling slope.
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H.F. Sync to approximately 20 mc.

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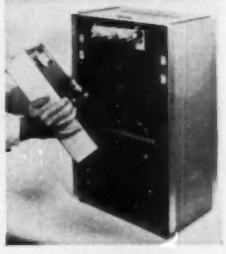
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A unique stacked-reel tape magazine is one of many space-saving secrets which enable Precision instrumentation recorders to out-perform conventional magnetic tape instruments many times their size. Other design secrets are push-button selection of function and speed, light beam end-of-tape sensing, front panel calibration and testing, interchangeable tape loop magazines, and all-solid-state plug-in electronics.

All the secrets of these recorders are unveiled in detailed new brochure 55B. Write for your copy today.



14-CHANNEL PRECISION RECORDER
Loaded magazines can be interchanged in 5 seconds.

P. S. – Here's an installation secret – two complete 14-channel analog (or 16-channel digital) recorders mount in only 51" of vertical rack space.

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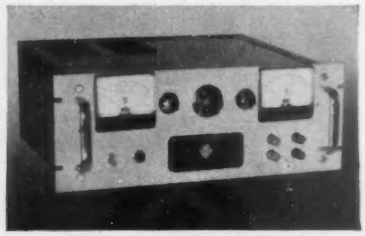
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164 CIRCLE 164 ON READER SERVICE CARD

NEW PRODUCTS

28-vdc source. Output is regulated 115-volts, 400-cps, three-phase. Conservative rating of power output is 500 va. Other features include high stability in frequency, phase, and voltage; short circuit protection; transient cushioning; and automatic phase lock circuitry.–Magnetic Amplifiers Div., The Siegler Corp., Bronx, N. Y.

Circle No. 336 on reply card

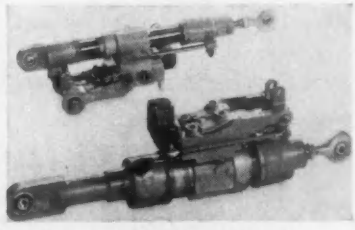


HIGHLY REGULATED

Rated at 0-100 vdc, 0-10 amp, continuous duty, the Model ST100-10 has a power output that is continuously variable over the entire range. The supply is transistorized and highly regulated: line regulation within 0.005 percent for changes between 100 and 135 vac and load regulation within 0.01 percent for changes from zero to full load. Ripple is less than 500 microvolts rms, overshoot is 1.0 percent max, and recovery time is less than 50 microsec. Price: $1,595.–Mid-Eastern Electronics, Inc., Springfield, N. J.

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ACTUATORS & FINAL CONTROL ELEMENTS



FLIGHT CONTROL UNITS

Flight control tandem servovalves and actuators now available have a one-piece sleeve and one-piece spool machined to reproduce the same flows

SAVE SPACE, WEIGHT AND MAINTENANCE with Versatile Compact MIL Spec Modules

For your electronic/electromechanical packaging problems, consult Oster specialists. Compact, transistorized, MIL spec, hermetically sealed, plug-in modules are available for numerous applications.

Typical building block basic units are illustrated. Temperature range is —55°C to +105°C. Basic units can be modified easily or completely redesigned to your specific requirement.

Oster engineers are specialists in creating densely packaged black boxes. These boxes can help you design more compactness and less weight into your systems. Phone or write your nearest John Oster office today.

GENERAL ENVIRONMENTAL CONDITIONS

A. Temperature—	—55°C to +75°C
B. Altitude—	—1000 Feet to +80,000 feet
C. Humidity—	Section 4.4.3 of MIL-E-5272
D. Vibration—	0.30 inch double excursion from 3 to 18 cycles per second and ± 2 g. acceleration from 18 to 500 cycles. (Without vibration isolators)
E. Crash Safety—	Repeated shocks of 30 g. with durations of 11 milliseconds
F. Salt Atmosphere—	Section 4.6.1 of MIL-E-5272
G. Fungus Growth—	Section 4.8.1 of MIL-E-5272
H. Sand and Dust—	Section 4.11.1 of MIL-E-5272

GENERAL PERFORMANCE SPECIFICATIONS

A. Gain Variation—	Less than 10% due to any given parameter extreme variation.
B. Linearity—	Better than 10% through the range of 3% to 80% of full output.
C. Noise—	Less than 5% of maximum output.
D. Phase Shift—	Less than 8 degrees.

Oster®

TYPE 9805-20—SYNCHRONIZER
Same as 9805-19 except Control Transformer Speed is 10 degrees/second—Min.

TYPE 9805-19—SYNCHRONIZER


Synchronizer

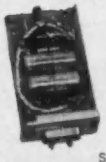
Motor Control Phase— 40/20 volts, 1.7 watts, 400 cycles
Motor Reference Phase— 57.5 volts, 2.2 watts, 400 cycles
Generator Excitation— 57.5 volts, 3.0 watts, 400 cycles
Generator Output— 0.3 volts/1000 R.N.M. Min.
Control Transformer Speed- 100 degrees/second-Min.
Control Transformer— John Oster Mfg. Co. 4053-19
Motor Generator— John Oster Mfg. Co. 6232-17

TYPE 9616-06—DEMODULATOR AMPLIFIER


Demodulator Amplifier

Input Impedance— Greater than 25,000 ohms
Output Impedance— 2830 ohms (Dual)
Voltage Gain— Greater than 115
Supply Voltage— 28.0 D.C.

TYPE 9616-07—SYNCHRONIZER AMPLIFIER


Synchronizer Amplifier

Input Impedance— Greater than 50,000 ohms
Voltage Gain— Greater than 250
Load— Control Phase of Motor Generator of 9805-19 or 9805-20

TYPE 9616-16—4-CHANNEL ISOLATION AMPLIFIER


4-Channel Isolation Amplifier

Input Impedance— 1200 ohms per channel
Voltage Gain— .98 ± .01 per channel
Load Impedance— 1200 ohms per channel
Supply Voltage— 48VDC

TYPE 9616-09—SERVO ACTUATOR AMPLIFIER


Servo Actuator Amplifier

Input Impedance— Greater than 50,000 ohms
Output Impedance— 400 ohms
Voltage Gain— Greater than 900
Supply Voltages— 100.0 volts D.C. 28.0 volts D.C.

TYPE 9616-15—RELAY AMPLIFIER


Relay Amplifier

Input Impedance— Greater than 15,000 ohms
Relay Closing Voltage— 150-175 Millivolts, 400 cycles
Relay Opening Voltage— 125-150 Millivolts, 400 cycles
Relay Contacts— 4 Pole, Double Throw—Dry Circuit
Supply Voltage— 28.0 V. D.C.

TYPE 9616-06—SUMMING AMPLIFIER (DUAL)


Summing Amplifier

Summing Inputs— 10 (per channel)
Gain— Nominal 1.0; variable from 0.1 to 10.0
Input Impedance— Dependent on Summing Channel. (50,000 ohms—500,000 ohms)
Load Impedance— Greater than 10,000 ohms
Supply Voltage— 28 V. D.C.

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it's the ultra low distortion – .005%
in this audio amplifier
that makes the big difference!

Here's a fifty-watt power amplifier with harmonic and intermodulation distortion of less than .005%. Distortion so low — you'd need special equipment to measure it!

That's why the UF-101A is a natural as a reference source, with a suitable oscillator, for low distortion measurement of power components, as well as a highly linear amplifier within the audio band.

The other characteristics of the UF-101A are equally outstanding. Phase distortion is negligible — ±2° maximum deviation from linear phase shift. Total hum and noise level less than 10 microvolts input equivalent. Frequency range is from 20 cps to 20 kc. For convenience, the UF-101A has taps for matched load impedances from 1 to 225 ohms.

Some of the applications of this ultra-low distortion amplifier are: checking the residual distortion of distortion-measuring equipment, reproducing non-sinusoidal wave forms faithfully, and as an ultra-low distortion, high power source to supply test benches. Write for full information on the UF-101A.

Other Krohn-Hite amplifiers include the direct-coupled, wide band DCA-10 (10 watts), and DCA-50 (50 watts). *Also, Krohn-Hite Oscillators, Filters and Power Supplies.*

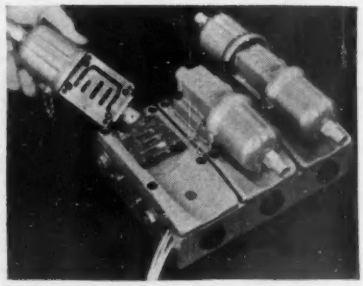
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NEW PRODUCTS

in two separate hydraulic systems. This construction assures retention of preset synchronization. Rectangular orifices in the servovalve make possible true linear flow. The units are meant for use in 4,000 psi, 274-deg F systems.—Hydra-Power Corp., New Rochelle, N. Y.

Circle No. 338 on reply card



CAN BE GANGED

Quick and easy combination of solenoid operated air valves is now possible with these new "add-a-unit" manifold-base, four-way valves. Anywhere from two to 10 of these units can be ganged to form common inlet, common exhaust, and common conduit channels. The single-solenoid, four-way, ¼-in. valve that is the first to be made available in the series is priced at $55; a double-solenoid model costs $70.—Mechanical Air Control, Inc., Detroit, Mich.

Circle No. 339 on reply card

DIGITAL FINAL ELEMENTS

Developed to eliminate the converters and other devices needed to adapt standard analog final control elements to digital control systems, this new line of devices includes digital positioners, regulators, force mechanisms, and variable speed transmissions. The elements operate directly from a digital computer, digital sensing element, or simple manual remote control station. This means perfect repeatability and stability and high accuracy; for instance, an 11-bit element yields 2,047 control points for an accuracy of 1 part in 2,047. Instantaneous response is another advantage, and system hunting is eliminated. For the digital positioner cylinder, stroke length is proportioned for each bit; for the digital force transmission, cylinder area is proportioned for each bit; and for the digital transmission, differential angular velocity is propor-

Just 0.1° F Change Gets Fast Action...

from a Fenwal THERMOSWITCH® Unit

Extreme sensitivity is an outstanding control characteristic of the Fenwal Thermoswitch Unit. Its outer shell is the heat-sensitive element . . . strut-and-shell assembly responds almost instantly to a change in temperature. Contacts are totally enclosed and protected. There's no thermal lag in the unit. *Control is positive and precise.*

Thermoswitch Units are easily adjusted, and cover the range from −100 to +1500°F. They're available as miniature, surface-mounted, or immersion types, with special variations to resist corrosion, extreme vibration, and shock. Current ratings up to 10A-115VAC. *Whichever unit you choose will be rugged and compact — simple, reliable, and inexpensive.*

Build better temperature control into your products with Fenwal Thermoswitch Units. For illustrated booklet, write Fenwal Incorporated, 298 Pleasant Street, Ashland, Massachusetts.



Series 17000
THERMOSWITCH Unit

Another example of how **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

CIRCLE 167 ON READER SERVICE CARD

MEASURE ABSOLUTE PRESSURES

with SPEED and PRECISION

With Wallace & Tiernan Aneroid Dial Indicators you get precision and fast response in all types of absolute pressure work.

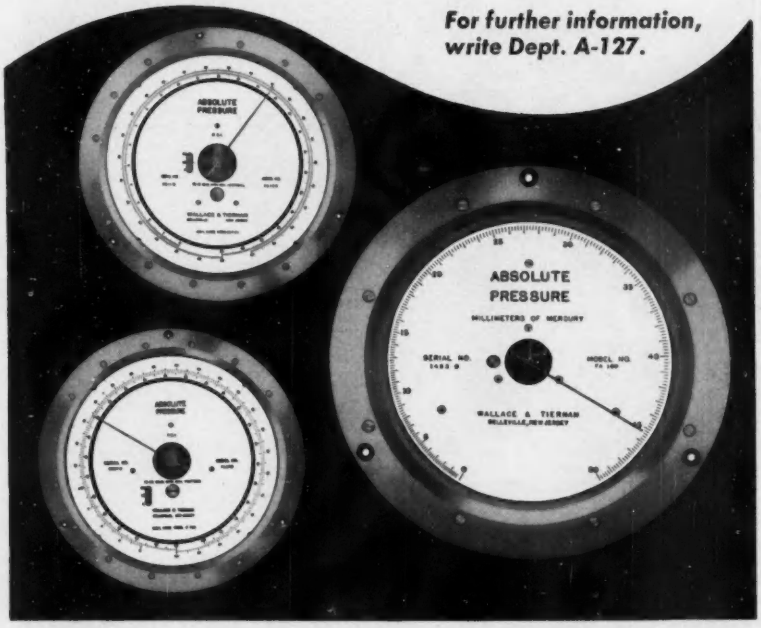
W&T Precision Indicators have many uses in research and development engineering. One is ideal for calibrating pressure transducers; another, for checking the calibration of flight instruments and ground support equipment. These instruments also keep constant check on continuous production-line work.

A W&T Absolute Pressure Gauge on the job means:

- ★ Accuracy 0.1% to 0.33%
- ★ Sensitivity 0.01% to 0.2%
- ★ Range 0.1-20 mm Hg to 0-500 p.s.i.a
- ★ No corrections
- ★ Light weight, small size

The accuracy of W&T Absolute Pressure Indicators approaches that of liquid columns... higher sensitivity assures faster response... large dial gives quick reading.

For further information, write Dept. A-127.



WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

168 CIRCLE 168 ON READER SERVICE CARD

NEW PRODUCTS

tioned for each bit.—Ferguson-Hille & Associates, Inc., Chicago, Ill.

Circle No. 340 on reply card

PRECISE POSITIONERS

The Series 18500 is a new line of magnetic positioning stepper devices designed for precise angular positioning of rotary components like pots, dials, and indicators. They may also be coupled to synchro transformers or predetermined pulse counters. The devices operate on number of pulses received, not on changes in phase angle or voltage. Action is all-magnetic; there are no ratchets, linkages, or contacts. — A. W. Haydon Co., Waterbury, Conn.

Circle No. 341 on reply card

COMPONENT PARTS



CU IN. REDUCERS

All of the units in a new series of miniature gear reducers occupy less than 1 cu in., but reduction ratios up to 2 billion to 1 are available. Input starting torque can be as low as 0.002 oz-in. The Size 11 unit shown above features maximum load torque of 100 oz-in.; starting torque, 0.005 oz-in.; input shaft moment of inertia, 0.02 gm-cm^2; backlash, 30 min at 5 oz-in. of reversing torque.—Elgin Micronics Div., Elgin National Watch Co., Elgin, Ill.

Circle No. 342 on reply card

NEW NOR

HS Series modules provide Sheffer Stroke gates for applications in digital systems. Unique properties allow complete digital switching network in-

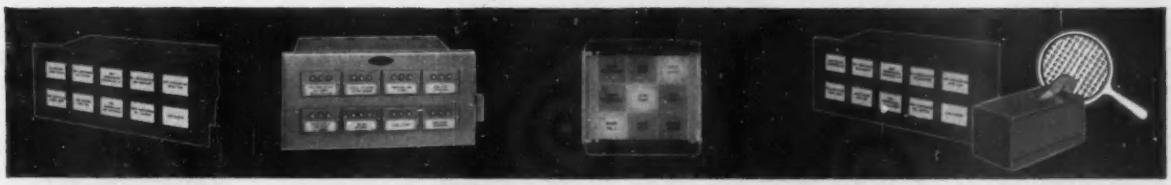


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AS VERSATILE AS YOUR REQUIREMENT

Lessens downtime by giving *instant visual* AND *audible alarms* when an "off-normal" occurs in your process. Time-saving—pinpoints trouble, permits faster correction and resumption of full production.

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Universal All-Purpose Annunciator System—can continuously monitor all points in your process. Wide choice of visual and audible sequences (optional flashing, ringback, multi-color visual, momentary lock-in, lamp reset, etc.) permits differentiation betwee.. :w and previously acknowledged alarms.

Digital Sequential Annunciator. Sequentially identifies your required off-normal points instantly. Handles any number of total alarm points. Clear binary readout. Millisecond resolution between points.

Miniature Solid State Annunciator—economical, lo-drain, intrinsically safe, no moving parts. Engineered for mounting in most standard miniature instrument cases. Compatible with high speed compact computer applications.

Recording Annunciator has bo.h flashing visual and audible alarm simultaneous with exclusive digital alpha-numerical recording of operations. No time-wasting decoding, no useless blank tape accumulation. Automatic, permanent, unalterable statistical record saves operator's time, reduces chance of operator error, permits closer supervision. Equally effective in manned or unmanned locations.

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Panalarm manufactures the most complete line of annunciators for information and control. For an optimum competitively priced Annunciator System for your plant, consult Panellit engineers. Sales and engineering offices in all principal cities.

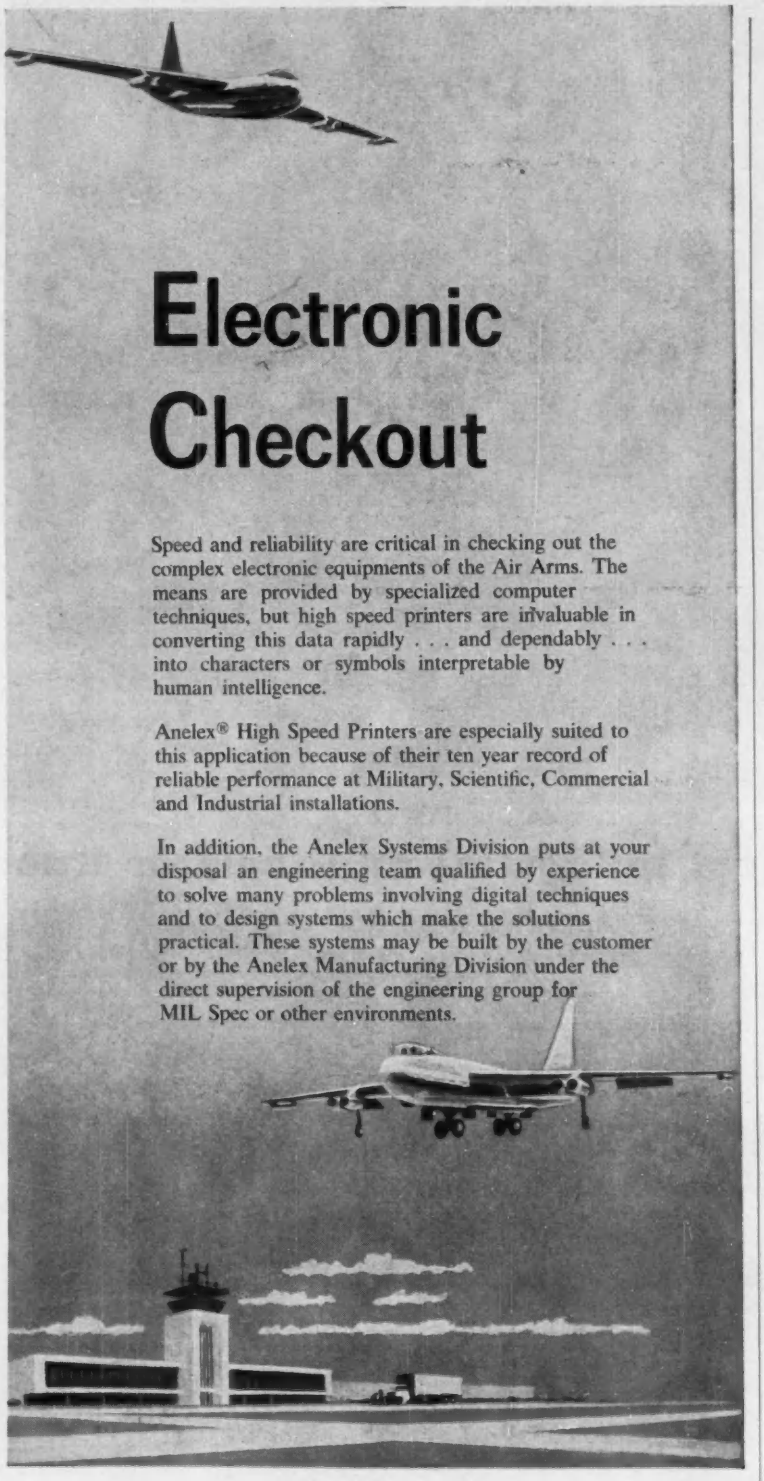


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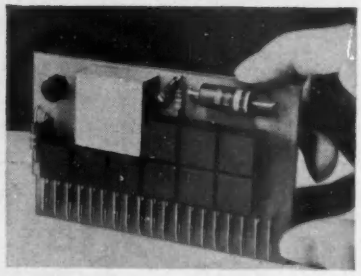
CIRCLE 169 ON READER SERVICE CARD 169



NEW PRODUCTS

cluding flip-flops to be built from these gates alone. Gates now available have from two to six inputs with provisions for interconnecting gates to provide more than six inputs. Used with the company's clocked flip-flops, two-level logic can be operated with a single-phase clock at 3 Mc.—Abacus, Inc., Los Angeles, Calif.

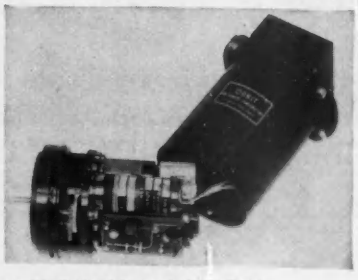
Circle No. 343 on reply card



USES ONE CORE PER BIT

A newly announced group of magnetic shift registers is unusually flexible. They achieve nondestructive readout, reversible data flow, reversible counting, code generation, and "corner turning" using only one core per bit. Available in 5, 9, and 10-bit length per module, they may be combined without limit. Shown above is a nine-bit register mounted on a standard printed circuit card. Frequency is 150 kc max for 12-volt ±20 percent dc power supply, with 6-volt input/output pulse.—Magnetics Research Co., White Plains, N. Y.

Circle No. 344 on reply card



PRECISION REPEATER

Shown above is a new 26-volt synchro servo repeater. Packed into the precision assembly are a gear train, motortach, control transformer, and transistorized amplifier and power supply. The device is said to have zero backlash between synchro control transformer and output shaft. Static accu-



by unique narrow-span DYNALOG* Electronic Controller

Temperature difference control within ½ of 0.1°C — that's what American Cyanamid demands for process evaporators at their Organic Chemicals Plant in Bound Brook, New Jersey. Boiling-point rise must be held at 108.5°C, since even slight variations affect product quality.

A Foxboro Dynalog Recorder-Controller, with full-scale span of only 5°C, provides the close control American Cyanamid requires. Control is held continuously within 1/20th of a degree of set point — with chart records for proof.

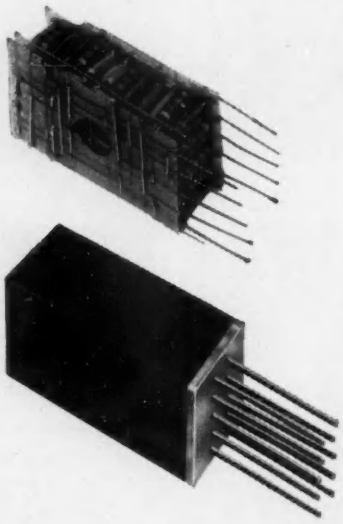
Cyanamid's Narrow Span Controller was installed in 1955. It's been running continuously ever since, virtually unattended. The only servicing or maintenance required on the Dynalog has been re-inking and chart changing.

Get the complete story on the exclusive Dynalog Controller, with full-scale spans as narrow as 5°F — the narrowest span available to industry today! Write for Bulletin 20-10. The Foxboro Company, 858 Neponset Ave., Foxboro, Mass. *Reg. U. S. Pat. Off.

FOXBORO
REG. U.S. PAT. OFF.

DYNALOG ELECTRONIC INSTRUMENTS

CIRCLE 171 ON READER SERVICE CARD



how do you play the numbers game?

The current numbers game consists of seeing how many components you can wedge into a small space. But there's a catch to it.

Some circuit modules may **seem** small until you string them together and find that interconnections and supporting structure take more space than the modules themselves. That's why it's important, in evaluating miniaturization, not to consider the module size alone, but to be concerned with the **over-all** size, including module, interconnections, and supporting structure.

New EECO MINIWELD circuit modules are designed with **over-all** system size in mind. They offer optimum miniaturization not only of modules, but also of interconnections and supporting structure. Add to this the reliability of proven circuits incorporating readily available standard catalog components rather than hard-to-get specials, the superior strength of welded rather than soldered connections, and you have an unbeatable combination of advantages.

We invite you to see for yourself at WESCON, Booth 1017.

Write, wire, or 'phone today for detailed information on the revolutionary new MINIWELD space-saving package.

ENGINEERED ELECTRONICS Company

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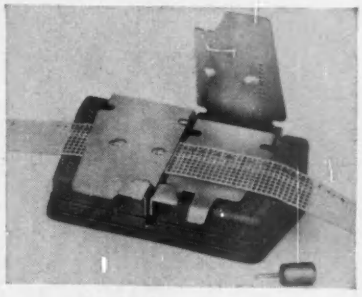
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Kimberly 7-5651

racy to within 0.25 deg max at 7-min synchro input, velocity constant of 500 deg per sec per deg, and slew velocity of 30 rpm are claimed for the unit. It measures 2 7/8 in diam by 4 7/8 in. long.—Orbit Instrument Corp., Syosset, N. Y.

Circle No. 345 on reply card

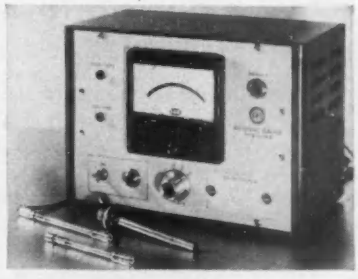
ACCESSORIES & MATERIALS



SPLICES TAPE

This handy unit permits rapid splicing of punched tapes for editing, mending, or correcting purposes. New information can be added and deletions made with no loss of desired information. The splices are strong and accurate; the device also cleans clogged punch-holes. Price: $28.—California Technical Industries Div., Textron, Inc., Belmont, Calif.

Circle No. 346 on reply card



SENSOR IMPROVEMENT

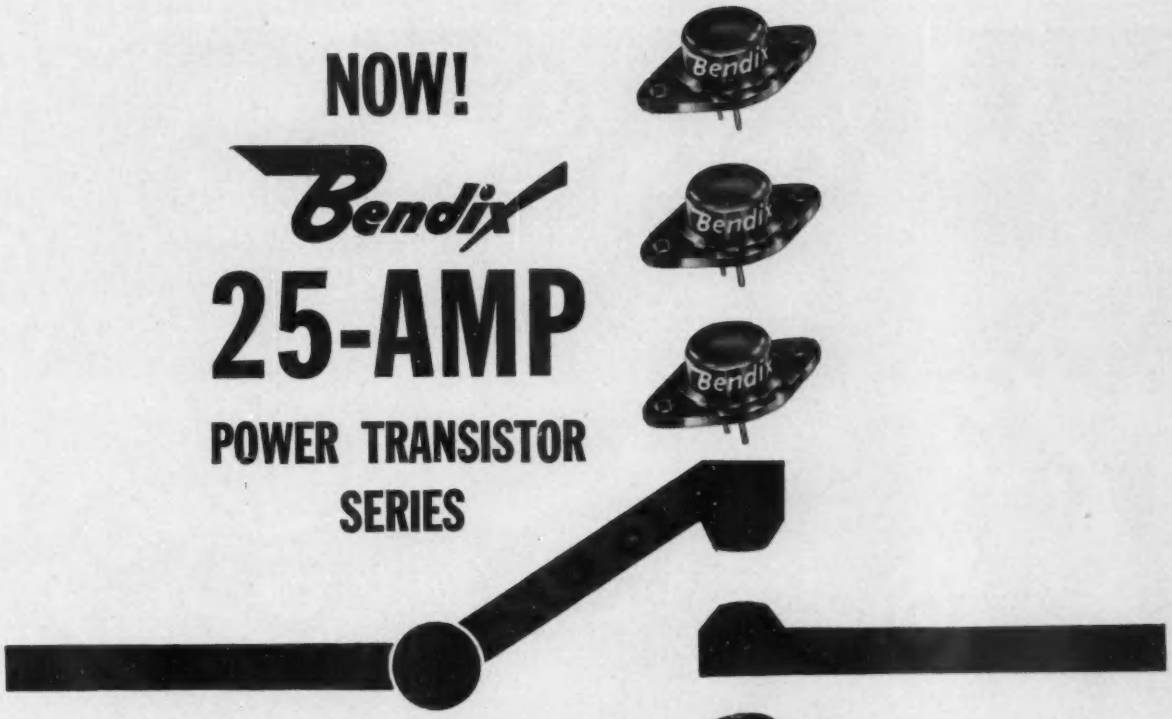
Two new sensing tubes greatly increase the versatility and adaptability of the LKB Pirani vacuum gage. Made by LKB Produkter (Stockholm, Sweden) the sensing tubes add to the number of potential applications for the Autovac, widely used as a continuous read-

NOW!

Bendix

25-AMP

POWER TRANSISTOR SERIES



Now in production by Bendix* are eight 25-ampere peak current power transistors capable of switching up to 1000 watts—and you can get immediate delivery on all eight types.

Newly improved in design, the transistors have a higher gain and flatter beta curve. The series is categorized in gain and voltage breakdown to provide optimum matching and to eliminate burn-out.

Current Gain hFE at Ic = 10 Adc	Maximum Voltage Rating			
	50 Vcb	60 Vcb	90 Vcb	100 Vcb
	30 Vce	40 Vce	70 Vce	80 Vce
20—60	2N1031	2N1031A	2N1031B	2N1031C
50—100	2N1032	2N1032A	2N1032B	2N1032C

For complete information, contact SEMICONDUCTOR PRODUCTS, THE BENDIX CORPORATION, LONG BRANCH, NEW JERSEY, or the nearest sales office.

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SEMICONDUCTOR PRODUCTS

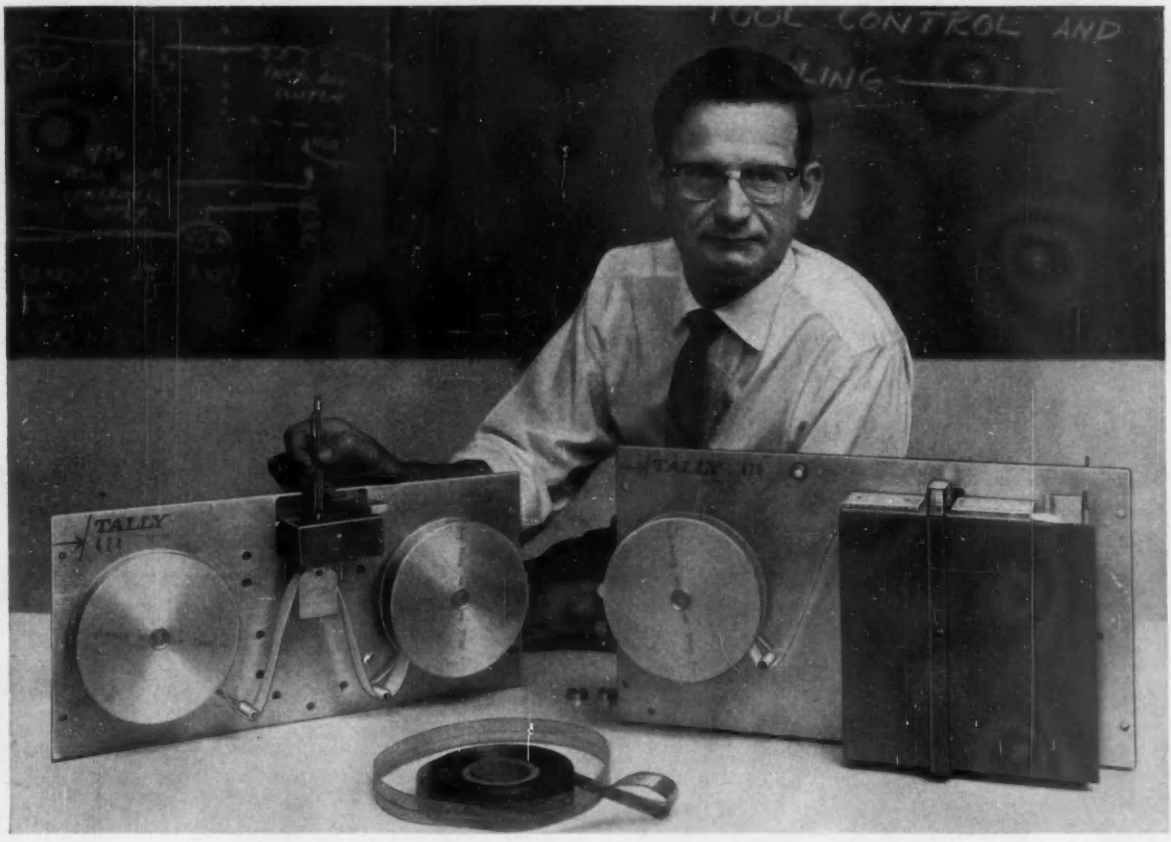
Red Bank Division

LONG BRANCH, N. J.

THE Bendix CORPORATION

CIRCLE 173 ON READER SERVICE CARD 173

• *A message of importance to engineers using punched paper tape equipment for machine tool control & data handling*



WHY TALLY READERS AND PUNCHES TALK EASY

You can talk to Tally punched tape readers and perforators with less input and output logic than any other equipment on the market. You can talk to Tally equipment faster. With only one command, your Tally reader will read and advance; your Tally perforator, punch and advance. You can read or punch 5, 6, 7, or 8 channels without modification. Oil mist lubrication provides whisper quiet operation. Their engineered simplicity means long term reliability.

Tally perforators operate *asynchronously* at any rate up to 60 characters per second. Their unique wire clutch drive lets you vary speed for slaving to other equipment, simplifying design of logical systems. Prices for perforators start at $1,000.

P.S. Problems in making complex programming tapes? Call us, we're making 4 to 16 channel guaranteed error-free punched tapes for many missile and satellite programs.

SEE US AT WESCON 552

...and long

Tally readers feature a reading rate of 60 characters per second in either direction, instantly reversible for rapid search and select. They have triggered tape feed readout with the rate controlled by external equipment. Full accountability is furnished by the Form C switch which provides positive hole/space sensing. Reader prices begin at $595.

Special Tape Systems Available

On request, Tally engineers will be happy to review your product requirements for special tape readers, perforators and reader-perforator systems. Please address Dept. 21

TALLY
REGISTER CORPORATION
1310 Mercer Street
Seattle, Washington
Phone: MAin 4-0760

COMING NEXT MONTH

The time is here to stop and take stock. Past special September anniversary issues have taught how to use advanced techniques and equipment. This year the theme is "Automatic Systems in the Plant". Seventeen detailed application studies will show how the latest in control solved problems in the following six areas:

- **Automatic Business Control**
  Information processing systems handle clerical work and supply data for management decisions both between plants and within a plant.
- **Automatic Process Systems**
  Complete processes under computer control: hot steel rolling mill, thermal cracking furnace, and power generating station.
- **Automatic Metalworking**
  This roundup of latest developments in machine tool control previews the September shows.
- **Automatic Unit Operations**
  Case studies of unique controls applied to four unit machines and processes.
- **Automatic Evaluation**
  In-plant automatic test, inspection and analysis systems save money by checking products.
- **Automatic Materials Handling**
  Programmed manipulators and conveyor controls are typical of control at work in materials handling.



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3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
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NEW PRODUCTS & BULLETINS

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317	328	339	350	361	372	383	394	405	416	427	438	449	460	471
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Name _____ *Title* _____

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310	321	332	343	354	365	376	387	398	409	420	431	442	453	464		475	486	497	508
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465		476	487	498	509
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466		477	488	499	510
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467		478	489	500	511
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468		479	490	501	512
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469		480	491	502	513
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470		481	492	503	514
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471		482	493	504	515
318	329	340	351	362	373	384	395	406	417	428	439	450	461	472		483	494	505	516
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473		484	495	506	517

Name _____ Title _____

Company _____

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1	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211	225	239	253	267	281	295
2	16	30	44	58	72	86	100	114	128	142	156	170	184	198	212	226	240	254	268	282	296
3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	268	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	269	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

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309	320	331	342	353	364	375	386	397	408	419	430	441	452	463		474	485	496	507
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464		475	486	497	508
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465		476	487	498	509
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318	329	340	351	362	373	384	395	406	417	428	439	450	461	472		483	494	505	516
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473		484	495	506	517

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480—Applying Control Timers, 50 cents
478—Servo Modulators, 65 cents
477—Basic Data on Process Control Systems, 50 cents
476—Three Ways to Simulate Dead Time, 15 cents
474—The Uses of Digital Computers, $3.00

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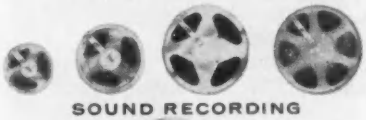
• • •

Federal Aviation Agency is still studying automatic landing systems for aircraft. The agency has awarded a contract to Lear Inc. to supply an airborne flight control system for automatic landings. In the Lear proposal, a computer will convert information from a ground-based transmitter to control signals that operate a modified Lear autopilot. First tests will concern only pitch control. After that, the complete system will be evaluated.

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hays



RAMBLINGS ON INSTRUMENTATION

The Temperature Measurement Caper

A chapter from "Mike Pipewrench, Private Eye" a new Service Training Manual we are preparing.

I'm crazy to get mixed up in this, I told myself as another .45 slug ripped my shoulder. Me, Mike Pipewrench, private eye. A blackjack glanced off my upper lumbar as I dragged myself to the window.

Inside, a hunched figure watched a weird machine. Little Rocco himself! Was I too late? I flung my six feet, nine-inches of bone and gristle over the sill, crouching for a catlike leap.

The hunched figure crawfished toward me, a Luger dangling from his clawlike fist. "You'll never get the secret, Pipewrench!" he screamed.

"Get smart," I told him, biting off the words. "You can't keep your formula for distilling gin from soybeans from the world forever." The Luger spouted flame and I clutched my other shoulder, fighting to control my temper.

"This is it, Pipewrench," cackled the hunchback. "You thought you'd found the secret when that showgirl at the Flamingo told you my process involved control of recycle gin, didn't you?"

I stalled. "What really tipped me off was when she mentioned a Hays *pneumatic* control." I kept a straight face as a slug ripped my solar plexus.

"That's right!" he shouted gleefully. "A Hays *pneumatic* control!"

I sneered, "Any child knows Hays doesn't have pneumatic control. Just electric controls. Best in the world. Joe Hays would spin in his grave if the company ever went in for pneumatic controls!"

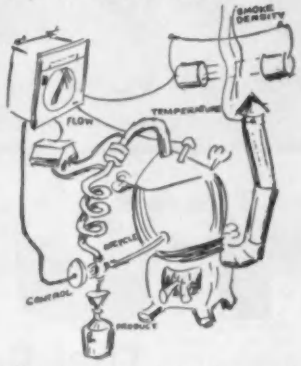
A willowy blond dashed into the room. "Mike!" she gasped, plastering herself against me. "Mike, I was going to tell you, honest. Hays *does* have a pneumatic control. It's made especially for them by . . ." The Luger cracked again and she collapsed on the floor.

I bent over her. "Made by who?"

Her eyelids fluttered. "F . . . . P . . . ." she gasped. Then it was all over. It just wasn't my night.

Little Rocco was talking again, agate eyes fixed on me. "Take a good look at the machine, Pipewrench," he snarled. "You'll never live to squeal. Note how I've combined part of the complete line of Hays temperature measurement instruments for precision recording of the distillation process."

A redhead in a leopard skin leotard slinked into the room. Little Rocco babbled on. "Note that the temperature of the gin is measured and recorded here on the Hays Universal Recorder, a Pneumatic Controller loading the pneumatic valve. Concurrently we obtain linear record of the square root flow characteristic of the gin, and . . . in the *fourth* recorder position . . . measure and record the nonlinear density of smoke from the fire."



"Stool pigeon!" the redhead screamed. Something flashed in her hand and Little Rocco writhed on the floor, the carved handle of a Javanese shiv between his shoulder blades.

"Nice work, baby," I told her. "He was too dangerous to live."

"He was about to spill the beans that the addition of the Hays Radiation Pyrometer would permit temperature measurement with the recorder beyond the 2500-2700° F. limit of the thermocouple," she pouted.

Somewhere a saxophone blared moodily. "I can't believe it," I muttered. "Hays *pneumatic* controls!"

"Everything changes, lover man," she said huskily.

I pushed her away. "Where did Rocco get his info?"

"No, no, Mike! Ask me *anything* but that!" I forced open her clenched fist. A crumpled paper dropped to the floor. As I bent to pick it up, I felt a shiv slip between my sixth and seventh ribs.

"Sorry, Mike," she sobbed.

I patted her cheek. "See you around, baby," I rasped.

I spread open the paper, flicked my hard blue eyes across it and swallowed it. "Hays Bulletin 60-B771-CP," I repeated. Only one thing to do—destroy those bulletins before people began writing for them. The saxophone bleated through the dark. I had a headache. It was one of those nights.

Paul Shaffer Jr.
President

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CYLINDERS · MILLING CUTTERS · RIVETERS and CLINCHERS

ing instrument in the vacuum range of 1 micron to 100 mm Hg. One tube, of Pyrex, is used for direct sealing to glass systems. Its major advantage is the ability to withstand bake-out temperatures up to 400 deg C when evacuated. The other tube, of stainless steel, is useful for installation in a metal system by means of a compression connector.—Consolidated Vacuum Corp., Rochester, N. Y.

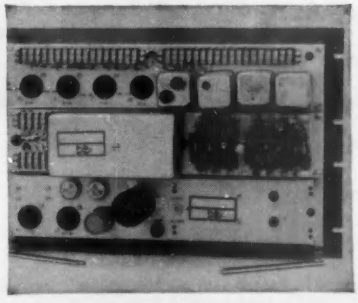
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5,000-DEG F CEMENT

A new ceramic cement for use at extremely high temperatures is now available for use as a surface coating for solid state devices, coating for thermocouples, and high temperature sensors in aircraft and wind tunnels, etc. Type A Astroceram will withstand temperatures to 4,300 deg F; Type B is capable of withstanding 5,000 deg F. The former may be air dried and adheres to metals readily. The higher temperature form must be fired to develop a bond; it exhibits very low thermal expansion, resulting in exceptional resistance to heat shock. – Instrumentation Associates, New York, N. Y.

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SYSTEMS



CONTROLS 256 FUNCTIONS

The new solid state Monitron is a remote control system which can be used to control up to 256 functions. The Monitron I coding unit is placed at the control point and the Monitron II decoding unit at the point where apparatus is to be controlled. The system is also applicable to monitor-

New tool for microminiaturization

Now Build Your Own Micromodules with RCA's Basic Micromodule Laboratory Kit

RCA's new Basic Micromodule Laboratory Kit provides a revolutionary new way to meet the challenge of microminiaturization. It places full facilities for building and encapsulating experimental Micromodules directly in the hands of your own design group. From breadboard to finished Micromodule, you can evaluate your own circuits, assemble and encapsulate to your own specifications.

COMPLETE KIT

The new kit provides all of the tools and instructions needed to convert many of your existing electronic-circuit designs into Micromodule equivalents: encapsulants, encapsulating mold, curing oven, cleaning materials, special microscope, special jigs, special air-abrading tools and automatic-control equipment—all are supplied with your Basic Micromodule Laboratory Kit. The only additional equipment you need to build your own sample Micromodules in your own laboratory is a tank of nitrogen and ten feet of workbench.

STEP-BY-STEP INSTRUCTIONS

The Design Manual and Instruction Manual supplied with the kit give the step-by-step procedures for converting to Micromodular form and for building your own micromodules. The Design Manual shows, for example, how to divide circuits into units to suit Micromodule requirements—how to determine the positions of microelements in the assembled Micromodule—how to lay out the wiring for interconnections between Micromodules—how to make mechanical layouts. The Instruction Manual clearly explains and illustrates all of the techniques for building and testing experimental Micromodules. The stock of microelements and other components provided in the kit can be used for a wide range of circuit designs.

DESIGN ADVANTAGES

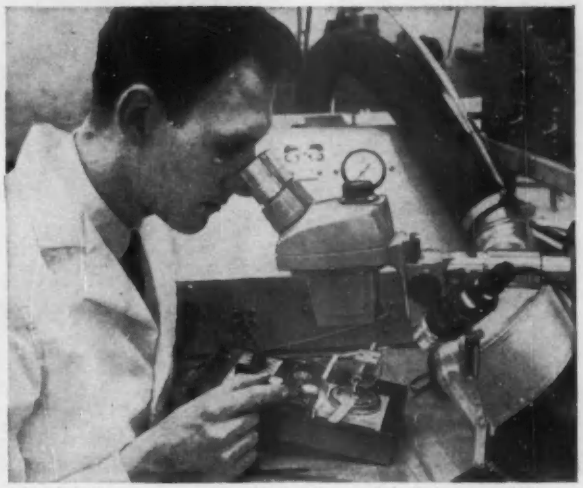
Give your equipment designs the inherent advantages of microminiaturization now, with the RCA Basic Micromodule Laboratory Kit—component densities to several hundred thousand parts per cubic foot, greater reliability through redundancy, room to improve accuracy, precision, control, sensitivity, and selectivity.

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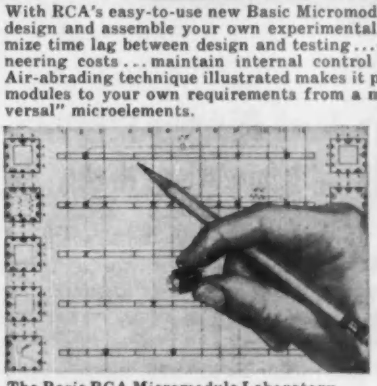
Your RCA Field Representative is ready to give you the details on the new RCA Basic Micromodule Laboratory Kit. He also has complete information on standard Micromodules available from stock for application in your new or existing designs. Remember, micromodularized end-equipment is probably your number one goal today—and it's ready for you now with RCA Micromodules. Give your local RCA office a call today!

For your copy of RCA's new, complete Micromodule Design Manual, send $2.00 today to RCA Semiconductor and Materials Division, Commercial Engineering Section H-56-NN, Somerville, N. J.

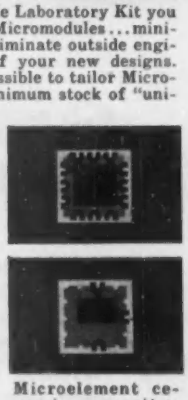
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With RCA's easy-to-use new Basic Micromodule Laboratory Kit you design and assemble your own experimental Micromodules... minimize time lag between design and testing... eliminate outside engineering costs... maintain internal control of your new designs. Air-abrading technique illustrated makes it possible to tailor Micromodules to your own requirements from a minimum stock of "universal" microelements.



The Basic RCA Micromodule Laboratory Kit is furnished with all components, equipment and manuals necessary for designing, assembling and encapsulating your own experimental Micromodules from worksheet to finished Micromodule.

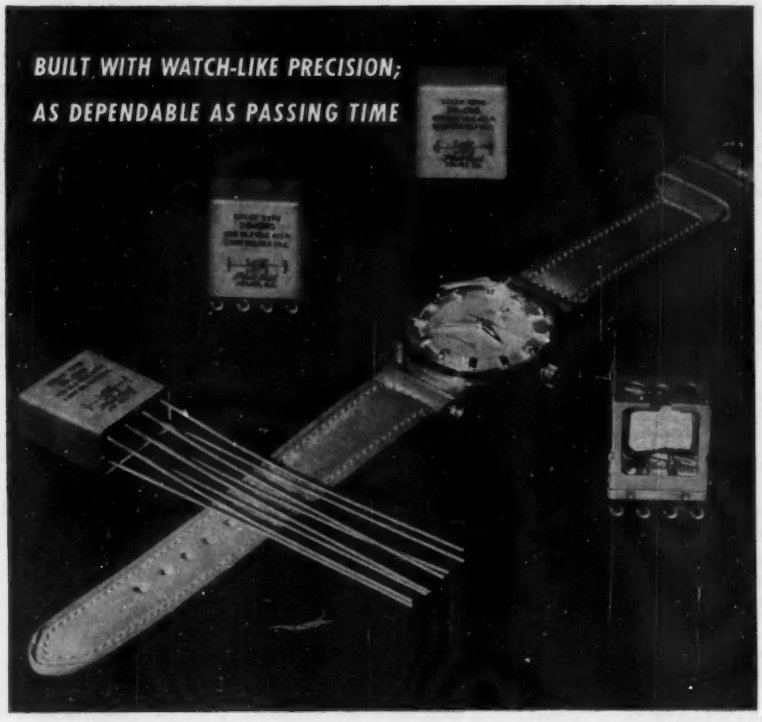


Microelement ceramic capacitor (magnified) with "universal" multiple terminations (top) can be abraded to give custom tailored capacitance values and provide the terminal arrangement you want (bottom).

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Width, .800	Also Low Level
Thickness, .387	circuit applications
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NEW PRODUCTS

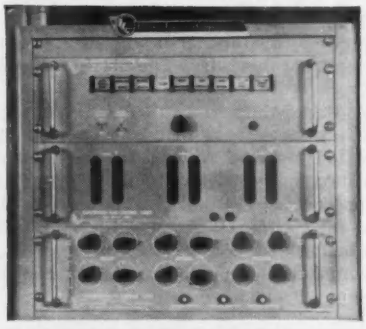
ing distant apparatus: continuous transmission to the control point of information of the status of a machine is possible.—Moore Associates, Inc., Redwood City, Calif.

Circle No. 349 on reply card

DIGITAL BLENDER

A new digital blending system offers flexibility for specific systems as a result of design that uses four basic functional building blocks. These are: the flowmeter assembly and control unit, incremental digital console, central control panel with displays, and localized remote control. The system is cable of meeting blending requirements with an error of $\pm \frac{1}{2}$ percent. Flowmeters feed flow rate data to the digital integrator which compares them to the preset conditions. Error signals (dc voltages) are fed to diaphragm motor valves on stock and additive streams.—Informations Systems, Inc., Los Angeles, Calif.

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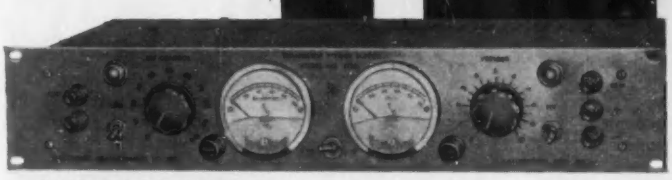
INDEPENDENT SEARCH

The recently announced ZA-821 tape search and control system is a solid state unit for magnetic tape that has its search function independent of tape speed. It employs a time code detection technique in the search function. System will automatically search and play back at any speed from $1\frac{7}{8}$ to 150 ips. Continuous decimal display shows the time code being searched. In operation the system searches, switches the transport to playback and provides contact closures for operation of auxiliary equipment. Unit occupies $15\frac{3}{4}$ in. of 19-in. rack space; maximum depth is 18 in. Price: $11,400.—Electronic Engineering Co. of Calif., Santa Ana, Calif.

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213A	0-50	0-1000	213AK
215A	0-50	0-3000	215AK
225A	0-75	0-2000	225AK
212A[1]	0-100	0-100	212AK[1]
2-212A[1, 3]	0-100X2	0-100X2	2-212AK[1, 3]
224A[1]	0-100	0-200	224AK[1]
221A	0-100	0-500	221AK
214A	0-100	0-1000	214AK
226A	0-100	0-2000	226AK
218A	0-100	0-3000	218AK
229A	0-150	0-300	229AK
228A	0-150	0-1000	228AK
230A	0-200	0-1000	230AK
231A[2]	0-300	0-100	231AK[2]
232A[2]	0-300	0-200	232AK[2]
233A[2]	0-300	0-300	233AK[2]
234A	0-300	0-500	234AK
237A	0-300	0-1000	237AK
236A[2]	0-600	0-200	236AK[2]
235A	0-600	0-500	235AK

[1] Has modulation input.
[2] Has additional 0-150 V DC output and 6.3 V AC CT output.
[3] Equivalent to two Model 212A's.

Why programmable? Because Regatron Programmable Power Supplies give the design engineer an extra margin of versatility. For example, in automatic test work, the programmable feature reduces control circuitry. In critical laboratory application, the programmable feature permits near-perfect reproducibility of test voltages.

There are other advantages too. The programmable feature provides for remote sensing. This provision eliminates the effect of voltage drops in power leads . . . places the point of regulation at the load terminals. And there's more.

For complete descriptions and specifications ask for Specification Sheets 3010B and 3023B.

® Registered U.S. Pat. Off. Patents Issued and Pending.

ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED
EATONTOWN • NEW JERSEY

CIRCLE 183 ON READER SERVICE CARD 183



New Industrial INFRARED Device...

THERMODOT® Radiation Thermometer Measures, Controls Temperature...Without Contact

THERMODOT is now being used in the production and testing of paper, glass, rubber, metals, and plastics. Designed for production plant operation, THERMODOT measures and controls the temperature of moving and inaccessible surfaces. Operation is remote, automatic, continuous.

High sensitivity provides reliable temperature measurements, even at low temperatures—lowest standard range 180-400°F full scale. Standard ranges extend to 4000°F. Standard response time is 2 seconds; 0.5 second available. An internal calibration source provides simple, rapid and accurate standardization.

THERMODOT measures the temperature of a remote object without physical contact. Operation is based on the fact that an object emits thermal radiation as a function of its temperature. An infrared lens, located in the THERMODOT optical head, is used to focus this radiation onto a sensitive infrared detector. The detector generates a signal voltage accurately proportional to the radiation intensity, and the signal is amplified to drive an indicator calibrated directly in temperature.

The THERMODOT radiation thermometer consists of an optical head and a power supply unit. THERMODOT is normally supplied with an indicator, indicating controller, or recording potentiometer. The optical assembly is housed in a sturdy, dust-tight enclosure and is insensitive to vibration and shock as normally encountered in the plant. Ambient temperature variations from 50-120°F have no effect on its operation.

SPECIFICATIONS OF THERMODOT MODEL TD-3

Working Distance ... Any range greater than one foot (prefocused at factory).

Speed ... Responds in 0.5 second.

Calibration ... Internal reference source for accurate standardization in seconds.

Emissivity Compensation ... Adjustable at control panel.

Ambient Conditions ... Unaffected by ambient temperature variations from 50-120°F.

For more information, write for Bulletin R-102, or see Thermodot operate at Booth No. 2018, ISA Exhibit, Sept. 26-30 in New York City.

RADIATION ELECTRONICS CO.

Dept. CE-8 • 5600 Jarvis Avenue • Chicago 48, Illinois • Telephone: SPring 5-2400

DIVISION OF **COMPTOMETER** CORPORATION

INFRARED COMPONENTS • INSTRUMENTS • SYSTEMS

BULLETINS AND CATALOGS

(400) CHART DRIVES. Insco Co. Div. of Barry Controls. Catalog, 12 pp. Covers a line of multispeed chart drives for use with strip chart recorders. Also presents application details, describes the advantages of quick chart speed changes, and cities the potential savings possible in chart paper costs.

(401) SYSTEM BUILDING BLOCKS. Digital Equipment Corp. Bulletin C-1000, 8 pages. This color-coded folder contains logic diagrams and complete descriptions, including input, output, and price data, on all 35 of the company's 5-Mc digital building blocks. Units include single, dual, and quadruple flip-flops, inverters, diodes, decoders, delay lines, clocks, pulse generators, amplifiers, converters, and others.

(402) DESICCANT DRYERS. Trinity Equipment Corp. Bulletin HA-308, 6 pp. Lists all technical specifications and capacities of the Trinity Heat-Les dynamic desiccant dryers, units designed to provide compressed gas or air with dewpoints below minus 100 deg F.

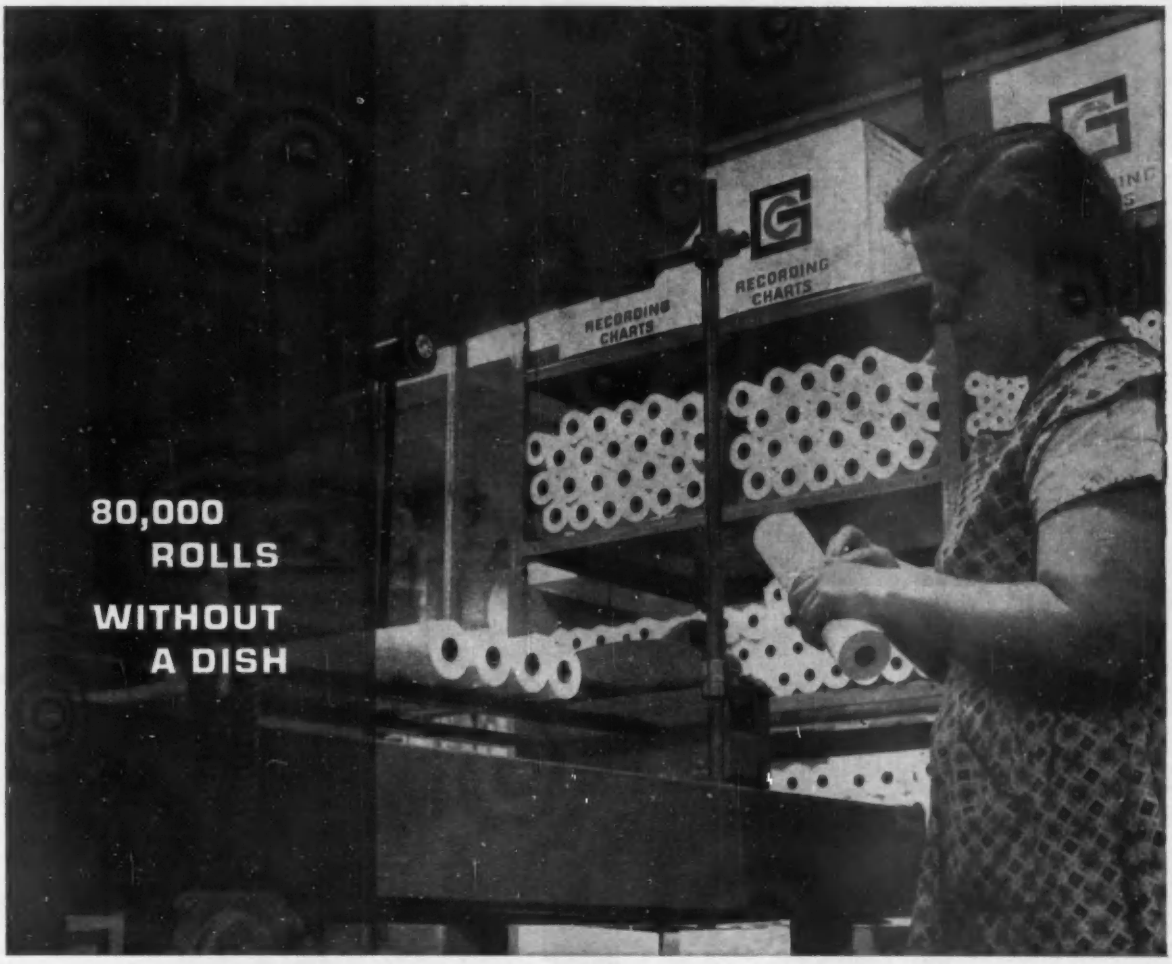
(403) THUMBWHEEL SWITCH. Chicago Dynamic Industries Inc., Precision Products Div. Catalog sheet, 2 pp. Two-color, illustrated sheet provides dimension drawings and complete technical data on a new multideck 8, 10, 12, or 16-position rotary thumbwheel switch which combines high reliability with a simplified design.

(404) TWO STORAGE TUBES. Hughes Aircraft Co. Two new brochures, now available, describe two direct viewing storage tubes. Specification brochure describes a 5-inch H-1027 tube featuring potted high voltage leads, high brightness, and extended storage characteristics. Second brochure provides details of 21-inch, H-1019 Typotron tube which writes 25,000 letters, numbers, or symbols per sec.

(405) MIL-SPEC RESISTORS. Ohmite Mfg. Co. Military Components Catalog 50-A, 36 pp. Covers the latest versions of those military specifications concerned with fixed and adjustable power resistors, precision resistors, rheostats, tantalum capacitors, and relays. Catalog actually reduces the formidable maze of military specifications to a fundamental basis that does much to simplify the writing of "type designations" and the ordering of military components.

(406) BIG RELAY CATALOG. Relay Sales, Inc. Claimed to be the most complete relay catalog ever published, this particular bulletin lists the lines of over 20 leading relay manufacturers. Data includes complete descriptions and prices. A new thumb-indexed table of contents assists the reader in finding any type of relay desired.

(407) SEALED LIMIT SWITCHES. Micro Switch, Div. of Minneapolis-Honeywell Regulator Co. Data sheet 171, 2 pp. Diagrams, photos, and lists of performance characteristics are used in describing the new 400 EN Series of subminiature sealed limit switches, units designed for the advanced environmental conditions found in aircraft, missile, railway, marine, and mobile applications.



. . . her conscientious workmanship watches over

RECORDING CHART RELIABILITY

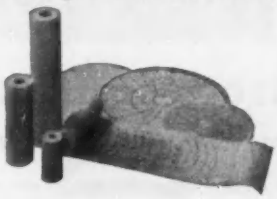
"Dish" occurs at the core end of a roll chart wound with incorrect tension. It means loose winding — and can lead to trouble.

Lois Deinhart, one of GC's experienced rewind operators, helps prevent this trouble from ever occurring. Here she is operating one of a battery of high speed precision rewind machines that roll strip charts to the exact length and tension required. Inspection by Lois and other skilled operators allows only perfect rolls to pass for shipment.

Because of special equipment and specially talented people, GC has become the world's largest manufacturer of recording charts—producing rolls, for instance, for virtually every make of strip chart recording instrument on the market. Over 70 different types of cores are available, each suited to the requirements of a specific instrument. End of roll indicators can be provided for visual, mechanical or electronic alarms.

GC's stock catalog lists over 15,000 different types of circular, strip and rectangular charts. We also design and produce special purpose charts to fit your most exacting needs.

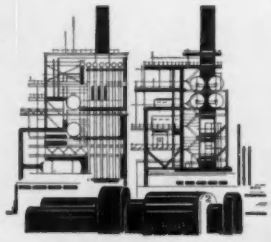
More than 5,000 chart users have come to rely on GC Recording Charts for accurate, dependable performance—chart after chart—year after year. In fact, GC Charts must be good to sell so well for so long. Try them yourself ! Let us send you our complete 1960 Stock List, and sample charts for one of your instruments.



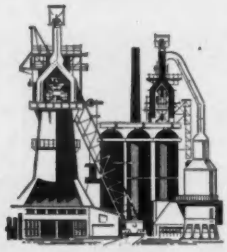
RECORDING CHARTS

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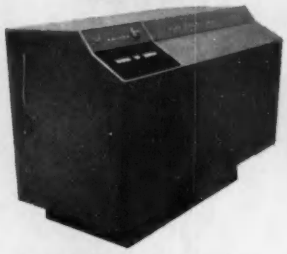
CIRCLE 185 ON READER SERVICE CARD 185



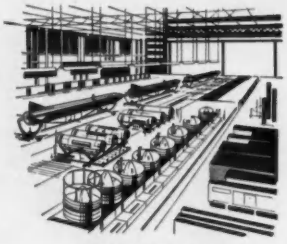
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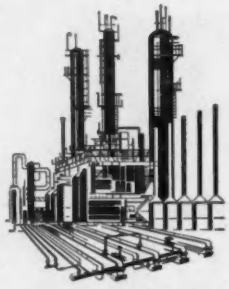
STEELMAKING



RW-300



MISSILE AND AIRCRAFT



OIL REFINING AND CHEMICAL

MANY "LEADERS" IN DIGITAL COMPUTERS, BUT ONLY ONE LEADER IN DIGITAL CONTROL COMPUTERS

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

a division of ***Thompson Ramo Wooldridge Inc.***

202 NORTH CANON DRIVE · BEVERLY HILLS, CALIFORNIA · BRADSHAW 2-8892

80% OF ALL DIGITAL CONTROL COMPUTERS NOW OPERATING IN INDUSTRY ARE RW-300 SYSTEMS

There are many companies which make various kinds of digital computers. These electronic machines serve useful purposes, ranging from the handling of payrolls to the solving of abstract mathematical problems, but they are not intended to *control* industrial processes. They are not designed to be connected directly to processes or test loops.



The Thompson-Ramo-Wooldridge RW-300 Digital Control Computer is built specifically for that purpose—to operate continuously a diversity of production processes in such industries as electric power, primary metals, missile and aircraft, electronics, chemicals, petroleum refining, pipelines, cement, and nuclear.

The RW-300 leads the field with 18 installations which have logged a total of 145,000 hours of operation—more than 16 years. It provides reliability exceeding 99% in around-the-clock applications. That is why you will see RW-300 systems in 80% of all industrial installations employing digital control computers.

For further information on the RW-300 and the associated engineering services, call or write Mr. Raymond E. Jacobson, Director of Marketing, Dept. CE-1218-1.

RW-300 computer controlling ammonia production at Monsanto Chemical Company plant, Luling, Louisiana.



TRW

CIRCLE 186 ON READER SERVICE CARD

Bulletins & Catalogs

(408) MAGNETIC TAPE RECORDERS. Precision Instrument Co. Bulletin 55, 8 pp. Covers the entire PS-200 Line of advance design, transistorized, magazine-loading, instrumentation tape recorders. Also includes information on brand new accessories.

(409) 10-TURN PRECISION POT. Helipot Div. of Beckman Instruments, Inc. Data sheet 60272, 4 pp. Describes Helipot's model 7212, a 10-turn bushing-mount potentiometer measuring only $\frac{7}{8}$ in. in diam, which, although properly classified as a precision pot, is said to be ideally suited for trim applications.

(410) HIGH SPEED COMPUTER. Digital Equipment Corp. Bulletin F-10, 4 pp. Text covers speed, memory size, access time, program features, input-output equipment, instruction format, instruction list, and prices. Illustrations include photos of the graphic output from the computer's cathode ray X-Y point plotter.

(411) MOTION CONTROL. Warner Electric Brake & Clutch Co. Bulletin P-78, 8 pp. Entitled "Tailored Torque", this brochure explains the Warner Electric operating principle, describes several clutch, brake, and clutch-brake applications, outlines specific operating advantages, and includes torque ratings and package dimensions for the complete line.

(412) RESISTANCE MEASUREMENT. Electro Scientific Industries, Inc. Design Ideas, Vol. 1, No. 2, 4 pp. This second issue of ESI's quarterly technical bulletin presents the first part of an article describing the methods and equipment used in making high accuracy resistance measurements with minimum effort.

(413) CHECKOUT EQUIPMENT. Packard Bell Electronics, Technical Products Div. Twelve 1-page data sheets. Covers the company's full line of automatic checkout equipment for testing missiles, aircraft, and other weapon systems. Units include control panels, power supplies, pulse generators, signal generators, amplifiers, and logic switching modules.

(414) VOICE MONITOR SYSTEM. Minneapolis-Honeywell Regulator Co. Catalog, 12 pp. Offers details on the company's new MultiTraK voice monitor, a unit which records 19 channels of information plus a time signal on one reel of tape. Small insert lists all specifications.

(415) PNEUMATIC CONTROLLERS. The Bristol Co. Bulletin DM058, 6 pp. Describes the new Series 624 indicating pneumatic controllers featuring a new advanced design control unit. Models and ranges are listed for temperature, flow, pressure, level, and humidity applications.

(416) COMPUTER TALK. Minneapolis-Honeywell Regulator Co. Pocket-size glossary, 22 pp. This booklet, entitled "Do You Talk 'Computerese'?", and compiled by E. A. Murphy, Jr., staff editor of Honeywell's *Instrumentation* magazine, defines some 82 terms peculiar to computer technology. Special emphasis is placed on industrial process control computers.

(417) NEW FUNCTION GENERATOR. Link Div., General Precision, Inc. Bulletin LP3555, 4 pp. Well illustrated three-color brochure offers details on a unique analog function generator designed to provide multivariable open or closed-loop functions. Concludes with a list of specifications, power requirements, and physical characteristics.

(418) AUTOMATIC TESTING. Optimized Devices, Inc. Brochure, 26 pp. Entitled "Handbook of Automatic Testing", this brochure actually consists of two booklets and several data sheets all dealing with precision voltage comparators and their use in automatic go/no-go testing. Illustrations include photo and typical circuit diagrams.

(419) AIR CONVEYING SYSTEMS. Flo-Tronics, Inc. Bulletin describes numerous variations possible in the engineering of air conveying systems for the bulk handling of powdered and granular materials. These include completely automated and programmed process controls. Diagrams show typical equipment and systems arrangements.

(420) COMPUTER SORTING. Remington Rand Div. of Sperry Rand Corp. Bulletin, 16 pp. Contains complete details of a computer program designed specifically for use on the Model I Univac File-Computer. Shows how this program permits the computer to sort one drum of 24-character unit records containing an identifier in the first word of an amount in the second word.

(421) SERVOAMP SPECS. Thermo Electric Co., Inc. Bulletin 91, 2 pp. Deals with a new high gain dc-to-ac servoamplifier with matched impedance motor. Lists full specifications and describes special features for various applications.

((422) IR CONTROL SYSTEM. Euclid Electric & Manufacturing Co. Bulletin E-300, 4 pp. Describes the optional as well as standard control features on the company's Sen-Tek Infrared Detector Control, an electronic device used in the detection of hot ingots, blooms, billets, slabs, and other radiant sources found in steel mills and similar industries.

(423) LAB AND TEST INSTRUMENTS. Leeds & Northrup Co. Folder E(6), 16 pp. Fully illustrated brochure contains specifications, application information, and prices of six different portable potentiometers, two dc galvanometers, an ac and a dc null detector, a guarded Wheatstone bridge facility, a universal ratio set, and two electrolytic conductivity indicators.

(424) TINY STRAIN GAGE. Baldwin-Lima-Hamilton Corp. Data Sheet 4331, 4 pp. Describes a new monofilament, subminiature wire strain gage and tells how it can be used to measure in crevices, fillets, corners, keyways, gear teeth, as well as in high temperature environments.

(425) NEW TAPE READER. Photocircuits Corp. Data Sheet 2120, 2 pp. Provides detailed information on the operation and application of the Model 100 photoelectric tape reader, first of its kind to use a printed armature motor.

(426) NUCLEAR INSTRUMENTS. General Electric Co. Bulletin GEA-7006A, 4 pp. Describes nine nuclear instruments available for immediate delivery from GE's Atomic Power Equipment Department, as well as a wide range of instrumentation system design services.

Employee Gift Matching

Another Good Way To Help Our Colleges And Universities

The business community continues to make an impressive record in giving badly needed financial help to our colleges and universities. This year the Council for Financial Aid to Education expects that business contributions to higher education will be well over four times their total of about $40 million a decade ago.

If these contributions, which were about $150 million last year, continue to increase at the present rate, they will hit the target of $500 million set for business aid to our colleges and universities in 1970. This is the amount which, the Council calculates, must come from business if these institutions are to have the money to do their job properly a decade hence.

However, it would be a fine thing both for the nation and the business community if that $500 million dollar target were hit well before 1970. This would put us ahead of a schedule (it is a conservative schedule) in getting on top of what remains one of the nation's most crucial problems—that of having its colleges and universities adequately financed which they are very far from being right now.

There is, we believe, one quite simple way by which financial support for higher education by business firms might be considerably speeded up. All that is required is that business firms generally abandon the idea that it is possible for every company to have a program to provide such support that is novel and distinctive, and that this is the only way that interests of prestige and good public relations can be served.

There are nowhere near enough good plans to provide financial help for higher education to equip even a small percentage of our business firms with one that is novel and distinctive. Also **there are a number of very good plans which, so far as we can tell, lose nothing of their value for prestige and good public relations by being used by a large number of companies.**

The Gift Matching Idea

One plan with these attractive characteristics is the plan by which companies match the gifts of their employees to colleges and universities, and now increasingly gifts to independent secondary schools. So far as we can discover the general plan was invented by the General Electric Company, with what it calls its Corporate Alumnus Program. Now, with variations on the same basic design, almost 100 companies have gift matching plans. We at McGraw-Hill are included in this number.

The gift matching plans vary considerably in detail. Some are limited to alumni of the schools to be benefited. In others any employee can participate by making a gift to an eligible institution. There are also variations in the maximum amounts of gifts by individuals and to individual institutions which will be matched. Some companies have "open end" plans; others limit the total to be matched in any one year. All of the plans, however, embody the same central gift matching idea.

When the plan was first launched some college administrators of little faith in the fundamental generosity of the alumni and friends of their schools expressed the fear that if gifts were to be matched they might be made smaller in the first place. The opposing view was that the possibility of having them matched would stimulate more and larger gifts.

Advantages Of Gift Matching

So far as we have been able to discover, the expectation that giving would be stimulated by gift matching has been validated by the experience with the plans. This has been our experience at McGraw-Hill. Some other important virtues of the gift matching programs have been summarized by

LEADERS OF SOME OF THE INSTITUTIONS WHICH HAVE SHARED IN THE McGRAW-HILL EMPLOYEE GIFT MATCHING PROGRAM EXPRESS THEIR VIEWS

"We particularly appreciate the fact that your grant is unrestricted, and can therefore be used for our area of greatest continuing need — the General Education Fund, from which faculty salaries come."

W. Boyd Alexander, Vice President and Dean of the Faculty
Antioch College

"We are grateful, not only for the financial support given to The Cooper Union by your company, but also for the stimulus it has provided our alumni in your employ to make annual gifts to their Alma Mater."

Edwin S. Burdell, President
The Cooper Union

"The gift matching program has a dual advantage. First, it acknowledges and repays a debt of honor to those colleges which, often at great loss to themselves, have trained and educated the men who are now among your personnel. This is most fair and equitable. Secondly, by offering to match up to a given limit the contributions of alumni, you encourage support of their own colleges on the part of graduates, who themselves are so indebted."

President Edward B. Bunn, S. J.
Georgetown University

"Thanks to your doubling of the annual gifts of one of our generous and loyal friends who works with you at McGraw-Hill, we are well on the way toward creating what for us will be an extremely helpful scholarship fund. This would not have been possible without the gift matching program."

C. Adrian Heaton, President
California Baptist Theological Seminary

Ernest T. Stewart, Executive Director of the American Alumni Council (1785 Massachusetts Avenue, N.W., Washington, D.C.) who would be glad to provide detailed information about them, and the names of companies having such plans. Of the gift matching idea he says,

> "*First*—it assures the corporation that its gifts go direct to those colleges and universities which have furnished it with trained manpower.
>
> "*Second*—it places responsibilities for the gifts on the institutions themselves and drives home the point that they must make a real effort with their own alumni.
>
> "*Third*—it leaves the final decision of corporate support basically to the employees."

For many companies which are fearful of complicating their relations with their customers by courting charges of favoritism if they provide direct financial support for any particular school or group of schools, this latter consideration can be of decisive importance.

The gift matching plan also has what for many companies is the very important virtue of being simply and easily administered. Some additional virtues of the gift matching plan, as seen by officers of institutions which have been beneficiaries, are indicated in the box at the top of this page.

Effective And Easily Managed

We at McGraw-Hill are well pleased with our gift matching program. It is a broad program in which all employees and a wide array of colleges and universities, both privately and publicly supported, are eligible to participate. We commend it as an effective and easily managed plan to provide urgently needed financial aid to higher education.

We also urge that business firms adopt this or one of a number of other very good programs of financial aid to higher education* rather than delay in the hope of hitting upon some quite new and distinctive plan. There are very long odds that such delay will prove unavailing. In the meantime our colleges will be losing financial help which it is profoundly in the interest of the business community and the nation to see that they get—and get fast.

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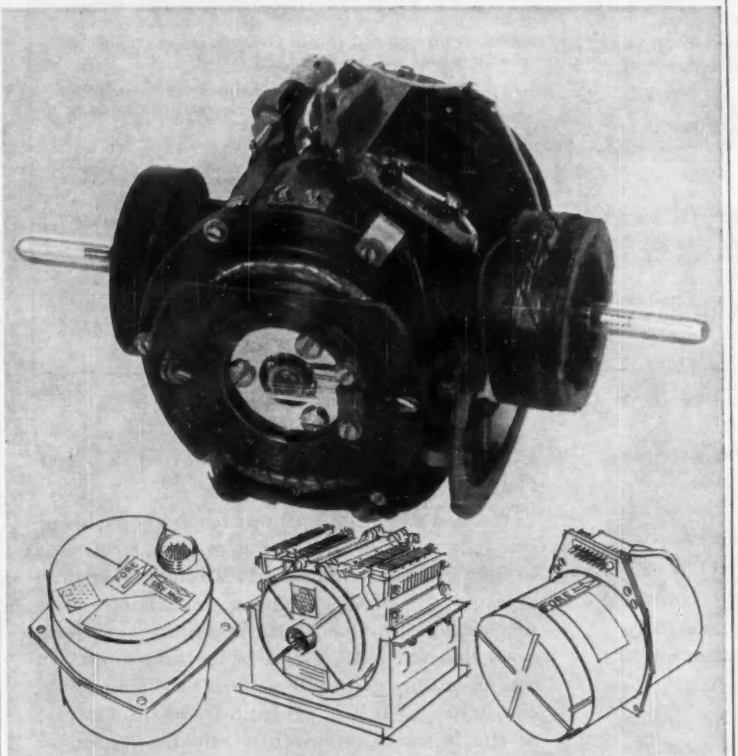
*An earlier editorial in this series dealt with tuition supplements as another good way to help our colleges and universities. Reprints of this editorial are available. So are copies of a "more or less socratic dialog," entitled, **A Business Wrestling with the Problem of Aid to Colleges and Universities.** It was prompted by the efforts of McGraw-Hill to find suitable methods of providing financial aid to higher education.

This message is one of a series prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nation-wide developments. Permission is freely extended to newspapers, groups or individuals to quote or reprint all or parts of the text.

Donald C. McGraw
PRESIDENT
McGRAW-HILL PUBLISHING COMPANY, INC.



ENGINEERING
REPORT
ON BENDIX COMPONENTS



BASIC WAY TO CUT GYRO COSTS

ADAPTABILITY OF BASIC BENDIX GYRO STRUCTURE BYPASSES EXTENSIVE DESIGN EXPENSE

There's a good possibility that our family of miniature vertical, free, and directional gyros can save you money. That's because they all have a basic gyro structure which—through proper orientation in case and proper selection of synchros, torquers, etc.—can answer many specific problems without the need of extensive design, development, and tooling cost.

These flexible gyros are self-contained, require no erection amplifier, and are highly adaptable in Radar Stabilization Systems, Guidance Control Systems, Bombing and Navigation Systems, and other such uses.

FEATURES:

- Operating life—1000 hours.
- Weighs less than four pounds.
- Electrolytic switches insure precise erection, long service life.
- Normal erection rate is 2°/min. with fast erection up to 120°/min.
- Flexible mounting—hard mount or vibration isolation.

To find out what these basic gyros can save you, write:

Visit our Exhibit at the Wescon Show—
Booths 1050-51

Eclipse-Pioneer Division
Teterboro, N. J.

The Bendix Corporation

District Offices: Burbank and San Francisco, Calif.; Seattle, Wash.; Dayton, Ohio; and Washington, D. C.
Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.

WHAT'S NEW

(Continued from page 45)

General Analysis Corp., a west coast company, like itself, engaged in computer application and contract work. C-E-I-R is currently negotiating with IBM to install a $12.5 million STRETCH-type computer in its present West Coast Research Center.

United Control Corp., Seattle, has purchased Electro Development Corp., a local aircraft and missile instrumentation firm (sales: $1 million).

Atlantic Research Corp., Alexandria, Va., has acquired Northeastern Engineering, Inc. of Manchester, N. H. The $2.5 million sales per year firm adds to its new parent company's manufacturing capability.

Micro-Path, Inc., Los Angeles subsidiary of United Industrial Corp., has formed a new instruments division based on the acquisition of the rights to the electronic and chemical devices for gas detection and analysis produced by Robert R. Austin Laboratories of San Gabriel (Calif.) Micro-Path plans expansion into other instrumentation areas.

Computronics, Inc. is the name of a new company formed in Denver, Col., to work in the field of components and systems for instrumentation, control, and data handling. Though Computronics is completely independent, Epsco, Inc. of Boston, Mass., is a major stockholder and has placed two members on the board.

Stromberg-Carlson's Electronics Div. in Rochester, N. Y., has formed a reactor control section to provide solid state controls for nuclear reactors.

Polarad Electronics Corp., Long Island City, N. Y. has made its first move toward diversification out of the field of microwave test equipment with the formation of a Scientific Instruments Div. Products will be aimed toward chemical, biological, and medical fields.

Lockheed Electronics Co. has set up a Systems Research Center in a new facility in Bedminster Township, N. J. Planned is a high level research outfit similar to the RAND Corp.; William K. Squires, director of the center, was formerly with RAND.

Standard Kollsman Industries, Inc. is the new name for Standard Coil Products Co. of Melrose Park, Ill.

IMPORTANT MOVES BY KEY PEOPLE

Gero New Information Systems Head; Johnson Rejoins CVA

Doane R. Gero has taken over as president of Information Systems, Inc. in a move announced by Board Chairman Albert F. Sperry. Gero succeeds Gifford K. Johnson who has been president of ISI since its tieup with Chance Vought Aircraft, Inc. earlier this year (CtE, March '60, p. 208).

Johnson will return this fall to Vought in Dallas to resume full time executive duties as a vice-president of the parent company. Sperry continues to assist in the direction of ISI's technical efforts.

Gero comes to the Los Angeles subsidiary from Giannini Controls Corp. where he was corporate vice-president and general sales manager. His previous affiliations included positions with Goodyear Aircraft Co., Cleveland Pneumatic Co. and Martin Co.

Hollander in New Computer Post at Hughes Aircraft

Gerhard L. Hollander is manager of a new general purpose computer department at Hughes Aircraft Co.'s ground systems group in Fullerton, Calif. He'll report to Monson H. Hayes, Jr., head of the group's computer laboratory.

Hollander joined Hughes in April from a position as section manager for systems management and control computer systems at Philco Corp.

Fluid Controls Institute Elects New Slate

At the spring meeting of the Fluid Controls Institute, Inc., held in White Sulphur Springs, Va., new officers elected were headed by Fred E. Weldon of General Controls Co., who was elected president. Elected 1st and 2nd vice-presidents respectively were Robert F. McCormick of Automatic Switch Co. and Eric A. Bianchi of Mason-Neilan.

Paul K. Rogers, Jr., of Skinner Electric Valve Div., The Skinner Chuck Co. is the new treasurer, and Samuel J. Reid of Barnes & Jones, Inc. was elected corporate secretary.

AIEE Names Linder, Others As 1960-61 Officers

Clarence H. Linder, a vice-president and group leader in the Electric Utility Group of General Electric Co. was announced as new president of the American Institute of Electrical Engineers at their summer meeting in Atlantic City, N. J.

The announcement of the election of eight district vice-presidents and a treasurer was also made.

Other Important Moves

Dr. Ernst H. Krause is now head of Electronic Systems Operations (formerly Range Systems Operations) at Aeronutronic, a division of Ford Motor Co., Newport Beach, Calif. He was formerly operations manager of Computer Operations and Range Systems. **Dr. S. Dean Wamless,** formerly manager of marketing of the division, has become general operations manager of Computer Operations.

Dr. Ralph P. Johnson has been appointed vice-president of the Electronics Divisions of Thompson Ramo Wooldridge, Inc., Los Angeles. He'll be responsible for the Los Angeles firm's five electronics divisions.

John D. Heasley is the new manager of Westinghouse Electric Corp.'s Industrial Electronics Dept. He succeeds **Robert C. Cheek** who recently became director of business system applications for the company.

Michel J. Fliegler formerly head of the potentiometer branch in the Ketay Dept. of the Norden Div. of United Aircraft Corp. has become chief engineer of the potentiometer division of Analogue Controls, Hicksville, N. Y.

George A. Hagerty has the new post of manager for process computers at General Electric Co.'s Computer Dept. in Phoenix, Ariz.

Dr. E. Singer has been appointed development supervisor at Shell Development Co.'s Emeryville (Calif.) Research Center. He will direct the application of machine programming methods to process design and evaluation in oil process engineering.

Z. R. S. Ratakski has joined Kearfott Div. of General Precision, Inc., Little Falls, N. J. as chief of research and advanced development in the Precision Components Div. He comes to Kearfott from the John Oster Manufacturing Co.

Gordon W. Smithson has been named chief engineer of Pratt & Whitney Co., Inc. He'll be responsible for all engineering activities for the West Hartford, Conn., firm.



AZIMUTH COUNTER

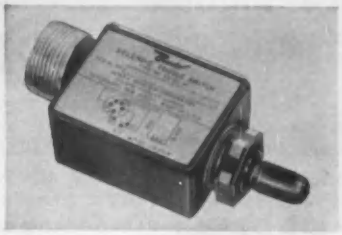
Presents angular information in 1° increments.



These lightweight digital display counters, featuring stainless steel types, are readily adaptable to fire control devices, aircraft and industrial instrumentation uses. Counter wheel numerals are $\frac{1}{16}$" high. They count in increments of 1° from 000° to 359° and repeat, with a cycle of operation infinitely repeatable and reversible. Available with either left-hand or right-hand input shafts. Request details.

SOLENOID TOGGLE SWITCH

Corrosion-resistant unit for severe operating conditions.



Developed for the severe environmental conditions outlined in MIL-E-5272A, this small, lightweight unit consists of a miniature micro-switch actuated by a toggle held in place by a solenoid-operated detent. In case of circuitry failure, the manually-operated toggle switch is returned to normal position automatically. Write for details.

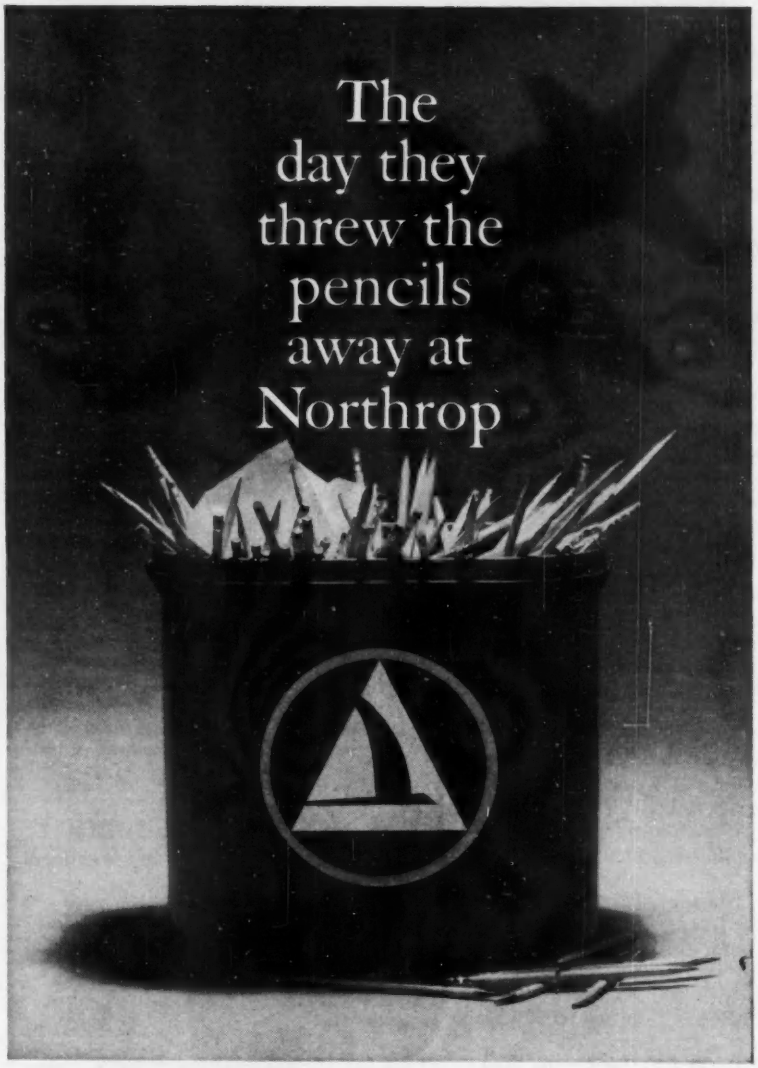
Manufacturers of
GYROS • ROTATING COMPONENTS
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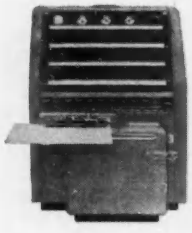
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Bendix

Teterboro, N. J.

CIRCLE 191 ON READER SERVICE CARD 191





The Northrop Corporation's Norair Division had a common and very costly bottleneck: internal paperwork.

The solution? *Automated data preparation* by means of a Friden Collectadata System. Located in key plant locations, Collectadata transmitters report virtually all internal transactions—about 45,000 daily—to central Collectadata receivers which record them into punched paper tape. At day's end, the Collectadata tapes are fed into Norair's electronic computer for high speed data processing.

Northrop estimates that this *completely automated* system will eliminate *two boxcars of paperwork annually*. How much could Collectadata save you? Call your Friden Systems Man or write: Friden, Inc., San Leandro, California.

THIS IS PRACTIMATION: Friden specializes in the practical application of automation principles to source data preparation and processing. © 1960 FRIDEN, INC.

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ABSTRACTS

Foreign-gas sensitizing

From "Techniques of Liquid Analysis", by L. A. Maley, Mine Safety Appliances Co. Paper presented at the ISA Instrumental Methods of Analysis Symposium, Montreal, June 1-3, 1960.

Most stream analyzers now in operation are sensitized to analyze a stream in its gas or vapor phase, even though in many cases the sample is taken from a vessel or line as a liquid. However, when a continuous analyzer can be set up to analyze the liquid stream directly, many expensive and difficult sample preparation problems can be eliminated. The author describes applications of liquid analysis by infrared, refractive index, and dielectric constant analyzers. A table describes the relative merits of these analyzers for particular types of streams.

The first and major consideration in sensitizing a selective-type infrared analyzer for a liquid problem is selecting the best possible gas or vapor to be placed in the detector cell. Placing the vapor phase of the liquid to be analyzed in the detector cell often proves to be the obvious and best solution. But frequently some completely foreign gas or vapor gives a much more satisfactory solution for these reasons:

- The vapor pressure of the liquid may be too low to give an adequate concentration for use in the detector.
- The liquid may absorb so strongly that it would be necessary to use an extremely thin cell (which is subject to clogging) to obtain the desired range, if the vapor of this liquid is used in the detector.
- The vapor phase of the liquid may not absorb in the same spectral region as the liquid.

To show how to handle liquids analysis with infrared when one or more of the foregoing problems exist, the author covers three typical applications in detail:

- Water in alcohol—here, rather than use water vapor in the detector cell, which would have entailed a very thin cell and absorption in the wrong spectral region, 100 percent carbon monoxide proved to be more suitable.
- Alcohol in ketone—100 percent ammonia was used, with quartz detector cell windows.
- Toluene in benzene—ethylene was placed in the beam combiner because it absorbs where benzene does not, and the quartz detector cell was filled with nitrogen saturated with toluene.

Medical instrumentation

From "The Continuous Automatic Measurement of Blood Pressure by Means of Control Equipment", by H. J. Wilmowsky. Regelungstechnik, December 1959, pp. 427-433. In German.

The article describes a system for automatically measuring the human blood pressure based on the usual bloodless sphyomanometric method using the Riva-Rocci cuff technique. The principle of this method is: the control criterion is the artery signal detectable in the elbow bend, and the cuff pressure is controlled in such a way that it equals either the diastolic or the systolic blood pressure. The stability conditions of a control loop of this kind are studied.

The procedure for measuring the diastolic pressure can be such that a pressure transducer picks up the pulsatory pressure variations, the signals then passing through a distortion eliminator so that they give a true picture of the actual blood pressure fluctuations. In this way it is possible to obtain as output from the pressure measuring device the diastolic pressure and, by superimposing blood pressure fluctuations, the systolic pressure.

Power instrument growth

From "Progress in Control Systems", by W. L. Chadwick, Southern California Edison Co. Paper presented at the ISA Power Div. Symposium, San Francisco, May 9, 1960.

The SoCal Edison engineering department examined the growth rate of use of instruments in the company's generating stations. In 1924 a 10-Mw generating unit was controlled effectively with 27 inputs and 11 outputs. A 66-Mw unit, built in 1944, required more than 300 inputs. Later this installation, reinstrumented for centralized control, used a total of 625 inputs and 250 outputs per unit. A pair of 200-Mw units placed in operation in 1958 employed 780 inputs and 400 outputs per unit in the control room. New generating units (210 Mw each) now under construction and which will apply computer control will have about 1,165 inputs and 430 outputs per unit.

The most recent operating unit (1958) hence has more informing instruments in its control room by a factor of 30 than the unit installed in 1924. The newest units now have more inputs than this early machine by a factor of 43. Outputs have increased to a number 40 times larger.



Virtually no maintenance (supplies can't be damaged even by direct short circuit of output); long life; extremely fast response; transient-free, ripple-free output; and wide input frequency tolerance—these are just a few of the major features you get in Sorensen Q and QR Series transistorized supplies.

They're ideal for critical applications like powering computer circuits, strain-gauge bridges, or low-level instrument circuits.

Q Series Supplies: Offered in 15 models with nominal output voltages of 6, 12, 28 vdc (adjustable 2:1, approximately) and up to 220 watts power capacity. Models available for either ±0.25% or ±0.05% voltage regulation (combined line and load). Available in either cabinet or 19" rack-mounting styles (15 and 25 W models can also be provided for dual rack mounting on a single panel).

QR Series Supplies: Feature wide-range adjustable output voltage—zero to rated voltage, continuously, with COARSE and FINE front-panel controls. Two standard models: 0-36 vdc, 4 amps max., or 0-75 vdc, 2 amps max. Output is regulated to within ±(0.02% + 1 mv). Output voltmeter and ammeter. Units are available for cabinet or rack-panel (19" x 5¼") mounting.

Get complete specs on these outstanding power supplies. Ask your Sorensen representative or write: Sorensen & Company, Richards Ave., South Norwalk, Connecticut.

SEE US AT BOOTHS 509-510 AT THE WESCON SHOW

Sorensen CONTROLLED POWER PRODUCTS

A SUBSIDIARY OF RAYTHEON COMPANY

New Sorensen catalog! Just off the press! 32-page catalog of more than 400 supplies plus valuable application data. Write for your copy today.

...the widest line lets you make the wisest choice

CIRCLE 193 ON READER SERVICE CARD 193

C AND S ELECTRONIC WEIGHING SYSTEMS

measure

FORCE·THRUST·WEIGHT

...high accuracy

...high stability

C AND S Electronic Weighing Systems provide the high accuracy and stability demanded today ... for example, to measure the thrust of jet engines, or to weigh aircraft. Systems supplied by Revere include:



CALIBRATION AND TEST
The CS-17 Force Calibrator with direct digital readout is the heart of completely instrumented hydraulic test stands used to calibrate load cells. Dead weight machines with a wide range of capacities are available for lab work.

WEIGHT AND CENTER OF GRAVITY
C AND S Electronic Weighing Kits do more than 90% of all aircraft weighing today. And major missile projects – Jupiter, Atlas, Polaris – are depending more and more on these kits; guaranteed accuracies of 0.1%

FORCE AND THRUST
Fully instrumented systems using C AND S Precision Load Cells in a wide range of capacities are custom-designed to test jet and rocket engines.

CALL ON REVERE ... WHEN YOUR PROJECT RATES THE BEST RATHER THAN "OFF-THE-SHELF" TREATMENT

when you want engineering abilities and specialized facilities in the fields of:

- Liquid Level Indication and Control
- Flow Indication and Control
- Flow Measurement
- High Temperature Wire and Cable
- Thermocouple Wire and Cable
- Thermocouples, Harnesses and Leads
- Electrical and Molded Harnesses
- Weight, Force and Thrust Measurement
- Determination of Center of Gravity
- Strain Gage Load Cells

neptune

REVERE CORPORATION OF AMERICA / *Wallingford, Conn.*
One of Neptune Meter Company's Electronic subsidiaries

NEW BOOKS

Basic Text

TRANSISTORS IN RADIO, TELEVISION AND ELECTRONICS. *Milton S. Kiver.* 424 *pp. Published by McGraw-Hill Book Co., Inc., New York.* $5.70.

Although this book is claimed to be written for radio and television technicians, in the opinion of this reviewer it would be a valuable addition to the technical library of any person who desires to gain a working knowledge of transistors and transistor circuit applications. From a clearly understandable explanation of modern electron theory in the first chapter, the text proceeds to discuss in an interesting style the theory and characteristics of junction transistors. Chapters 4 and 5 discuss in moderate detail various forms of transistor amplifiers and oscillators and how they operate.

In Chapters 6 and 7 the use of transistors for many functions in radio and television receiver circuits is investigated, followed by a presentation of more diverse uses of the transistor in the general realm of electronics. Gating, switching, flip-flops, and power regulation are among the areas covered in Chapter 8. Next, the operational principles of some of the less widely known transistors developed to date are described. Practical hints for transistor circuit servicing are discussed in Chapter 10, while Chapter 11 presents a series of simple experiments designed to provide a first hand understanding of transistor characteristics and peculiarities. Chapter 12 completes the text with an introductory analysis of transistor amplifier design to provide a general familiarity with the problems involved. Use of mathematics is minimized throughout.

At the end of each chapter are presented questions which cover completely the pertinent areas within the chapter and provides a means of testing the reader's understanding of the material. This book could be used for instruction courses or home study. It includes a bibliography, index, and characteristic data of some widely used junction transistors.

A. N. DeSautels
Maico Electronics, Inc.

Revised Text

SERVOMECHANISM PRACTICE. *W. R. Ahrendt and C. H. Savant, Jr. 2nd edn. 595 pp. Published by McGraw-Hill Book Co., Inc., New York, N. Y.* $12.50

This revised, considerably expanded

More Accurate Level Reading of LOW TEMPERATURE LIQUIDS . . .

JERGUSON

Large Chamber

NON-FROSTING* GAGES

YOU get the highest possible accuracy of reading on low temperature, low boiling point liquids with the patented Jerguson Non-Frosting Gage in the New Large Chamber model . . . because it insures less turbulence at the meniscus, and clear vision at the vision slot.

This new Jerguson model has 6 times larger area at the meniscus than the standard gage, so that there is a marked reduction in turbulence with light gaseous fluids that tend to boil or surge. Moreover, the problem of frosting encountered with these liquids has been eliminated by a patented frost preventing unit extending from the gage glass. This special transparent unit projects beyond the cover bolts and prevents frost from building up over the vision slot.

Here's a dual feature gage that assures greatly increased accuracy of reading for the process industries. If you have a problem with light gaseous fluids, or with gage frosting, it will pay you to investigate the new Jerguson Large Chamber Non-Frosting Gage . . . reflex or transparent.



Jerguson Large Chamber Gage, Transparent Type, with the patented Non-Frosting Gage Glass Extension. Write for literature on this gage, and on other non-frosting Jerguson models.

**Patented*

JERGUSON

Gages and Valves for the Observation of Liquids and Levels

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100 Adams Street, Burlington, Mass.

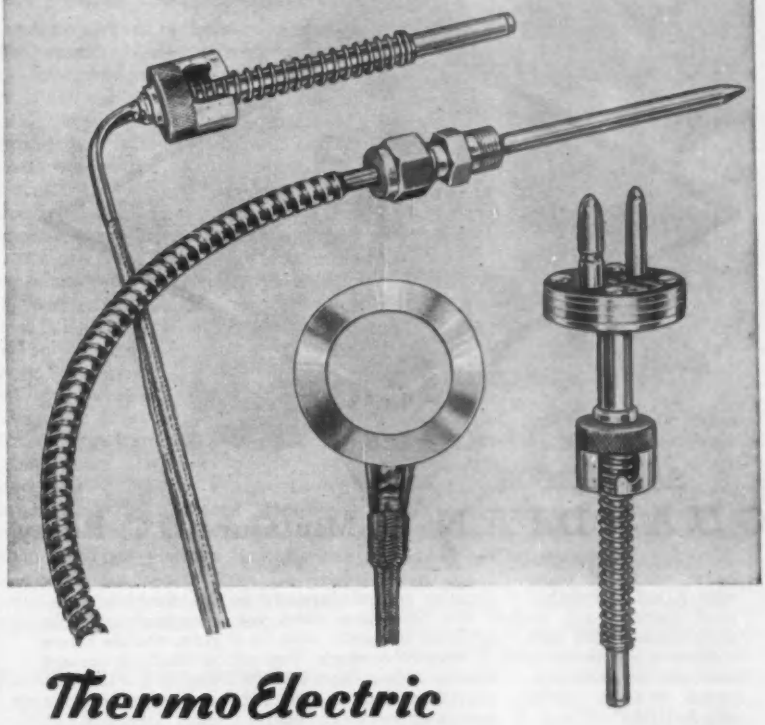
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Peak Performance—

economy on the job!



Thermo Electric

Miniature Thermocouples

You can obtain a Thermo Electric Miniature Thermocouple for peak performance and economy in almost every application! Those illustrated are available in a wide variety of sizes, standard thermocouple materials, adapt to many applications.

Protected thermocouples are extremely sensitive, give fast response to minute temperature changes. The measuring junction is welded or silver soldered to the tip of the thin-walled "Ceramo" metal sheath. Ideally used in corrosive liquids or gasses—and many pressure applications. For quick-coupling versatility, the spring-loaded bayonet-lock thermocouple is tops! You can use one "couple" at various depths with different adapters. With spring-loading, tip contact is always maintained. The bayonet type is highly sensitive, fast responding, for use in pump and engine cylinder heads, turbine housings, pipes, electric motors, generators, plastic extruders and molding machines.

Gasket Thermocouples measure surface temperatures in all sorts of stationary or moving machinery.

T.E. also produces stagnation, exposed junction and shielded thermocouples for use in air, gas or vaporous atmospheres.

write today for Bulletin 1256-11

Thermo Electric CO., INC.

SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.

CIRCLE 195 ON READER SERVICE CARD



Series 2505
GUARDIAN® Miniature D.C. Relay

◆ Absolute reliability! Greater control capacity! In this complete, compact, hermetically sealed unit Guardian gives you amazingly reliable performance and extra switching capacity with its 6 pole, double throw contact combination *plus* 5 ampere contacts. You get all this high current and greater switching capacity in less than 1.1/2" x 1 7/32" x 1 7/32" max. space. Weight: .23 lbs., maximum. Unit meets or exceeds specifications MIL-R-6106-C (Class B) including minimum current, also vibration of 20G's to 2000 cycles. Contacts are staked, not welded. Guardian's exclusive "Fluxless Solder" sealing prevents internal contamination. Header pins may be rotated without damage to glass seal.

SPECIFICATIONS

Operating Voltage: 29 volts dc maximum
Pick-Up Voltage: 18 volts dc maximum.
Nominal Coil Voltage : 24-28 volts dc.
Coil Current: 200 MA maximum.
Release Voltage: 0.5 volts minimum.
Contact Combination: 6PDT
Contact Rating: @ 28 volts dc /115 volts—400 cycles
resistive dc— 5 amp
inductive dc— 2 amp
motor dc— 1.5 amp
Contact Bounce: 0.002 seconds maximum.
Dielectric Strength: Sea level—1000 volts RMS, altitude—350 volts RMS.
Rated Duty: continuous
Operating Temperature: −70° C to +120° C
Operating Cycle: 50,000 minimum.
Operating Time: 0.007 seconds maximum.
Release Time: 0.005 seconds maximum.
Vibration Acceleration: 20 G's to 2000 CPS
Weight: .23 lbs. maximum.
Applicable Specification: MIL-R-6106-C (Class B-8) including min. current

Visit Guardian's Booth No. 840–841 at 1960 WESCON SHOW

Outline Drawings and Qualification Test Reports Available Upon Request

GUARDIAN ELECTRIC
MANUFACTURING COMPANY
1558-J W. CARROLL AVENUE CHICAGO 7 ILLINOIS

edition continues the philosophy of the original edition, namely the presentation of practical application information on servomechanism components. The principal modification is the expansion of content to include transistor and transistor-magnetic amplifiers; gyros; as well as up-to-date material on accelerometers, electromagnetic torquers and forcers, and pneumatic systems. The over-all organization of the book is considerably improved. Additional theoretical background is provided with the primary purpose of supporting the practical component coverage.

Although this book does not have the complete mathematical components descriptions of *Control System Components* by Gibson and Tuteur (McGraw-Hill, 1958) it nevertheless preserves its unique flavor of presenting in detail the problems involved in putting together components in a working, high performance servomechanism. The lucid but rigorous reasoning emphasizes the physical description of performance and instability phenomena. It is remarkable how little of this material has been made available in other texts in as convenient a form.

Not only are the major electromechanical components covered, but the book goes on to discuss gearing problems; bearings; effects of backlash and stiction; as well as methods of zeroing, aligning, and testing the finished package. These topics are obviously of major importance where performance of a high gain loop depends so critically on the quality and assembly of mechanical hardware.

Servomechanism Practice is recommended to engineers who deal with and must debug actual equipment. The relative independence of most of the material of advanced mathematics should make the book suitable for the requirements of such personnel as senior technicians.

Language of Math

GERMAN-ENGLISH MATHEMATICS DICTIONARY. *Charles Hyman.* 131 *pp. Published by Interlanguage Dictionary Publishing Corp., New York.* $9.

This book contains more than 8500 entries collected from textbooks and other works in the field of mathematics. Definitions are illustrated by usage in sample phrases.

VARIAN
Potentiometer
RECORDERS

Preferred for real differences, for example . . .



7. ADJUSTMENTS MAKE THEM

VERSATILE

Zero is adjustable—left, right, center, or any uneven division of the chart to fit each particular use. Also, ranges from 0-9 millivolts to 0-100 volts. Such options as temperature recording are provided by interchangeable chassis and matching charts and scales.

1% accuracy; 1 or 2½ seconds full-scale balancing time; portable, bench top or panel-mounted versions; single channel units weigh 15 pounds, dual channel 35 pounds; prices from $365; wide range of speeds and other options described in Varian literature. Write the Instrument Division.

VARIAN associates

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CIRCLE 214 ON READER SERVICE CARD

DESIGN NOTES on

Control by Rotary Switches

No. 2 of a series

Rotary-switch Contact Structures

An important difference between the rotating-blade switch and the cam-operated switch is the way contacts are made and broken. In the rotary switch, a *wiping contact* is provided. The movable contact wipes across the full width of the stationary contact(s), clearing away dirt or corrosion as the switch is operated and keeping the contact area clean so as to minimize contact resistance and consequent heating. In some types of light-duty switches, the wiping action occurs at one side of each contact. For switches that must handle moderate or heavy currents (5 amperes to 200 amperes), the wiping action usually occurs on both surfaces of one contact (usually the stationary contact) and on the inner faces of the double-blade contact that mates with it.



Rotary-switch Drive Mechanisms

Two general types of drive mechanism are used with rotary switches. They are the direct drive with detent and the snap-acting type. The direct drive is generally used with light-duty switches or with switches having more than eight stationary contact positions. The detent action holds the movable contact in alignment with a stationary contact by spring loading. This is often accomplished by having the stationary contact slightly below the surface of the insulating deck and depending on the resilience of the movable contact to hold the contacts in line. While this construction is often adequate for light-duty switches, a more positive detent action is required where maximum life, reliability, and stability are necessary. Such action



Cutaway view of Type JR Switch showing positive detent mechanism.

is provided by a separate detent mechanism in which the detent springs are not part of the electric circuit and the position of the contact-carrying rotor is established by a star wheel that engages spring-loaded balls or rollers.

With the direct drive, the speed of contact opening or closing depends on the way the operator turns the switch handle. In direct-current circuits, it is desirable to make and break contact quickly. One way to accomplish this is by using a snap-acting drive mechanism. Turning the switch handle winds a spring and, when enough energy has been stored up, the spring snaps the movable contact quickly into the next position. Because of the mechanics involved, this action is generally provided only for four-position switches although it can, under some circumstances, be furnished with eight-position switches.

Rotary-switch Circuit Possibilities

One of the most important advantages of the rotary switch is its adaptability to control of complex circuits. This aspect of design will be discussed in the next advertisement in this series.

ESCO Bulletin No. 8A, containing useful information on the construction and application of rotary switches, as well as examples of ESCO switches that utilize the design principles discussed in these advertisements, will be sent you on request.

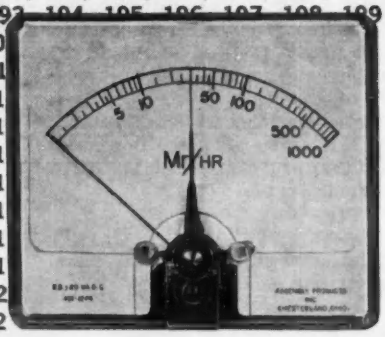
ESCO of WEYMOUTH

ELECTRO SWITCH CORP.

Weymouth (Boston 88), Massachusetts

CIRCLE 197 ON READER SERVICE CARD

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1211, 1212, 1213, 1214, 1215, 12



10,000,000 MAKE-BREAK CYCLES —NOT ONE FAILURE!

The control dependability of the A. P. I. meter-relay is fact, not fancy. Ten million perfect operations is just one test result; nearly twenty million decisive make-break cycles were achieved in another test. Exceptional? Not for an A. P. I. meter-relay. Once the contact on the pointer arm "makes" with the set-point contact, the two are firmly locked together by an exclusive A. P. I. design feature; a perfect control circuit is formed every time. This is one of the reasons A. P. I. meter-relays are used for such critical applications as controlling life-sustaining oxygen equipment, monitoring radiation levels and safeguarding vital communications circuits. The meter-relay is both an indicator and controller, sensitive enough to operate on very small microampere or millivolt inputs without amplification. Simple, accurate, applicable to any electrically-measurable variable, the A. P. I. meter-relay is well worth investigating as a low-cost monitoring and control device. You can start by writing for Catalog 4G.

api **ASSEMBLY PRODUCTS, INC.**
Chesterland 77, Ohio

MEETINGS

AUGUST

Fourth National Heat Transfer Conference and Exhibit, sponsored by AIChE and ASME, Statler Hotel, Buffalo, N. Y. Aug. 14-17

Western Electronic Show and Convention (WESCON), Memorial Sports Arena, Los Angeles, Calif. Aug. 23-26

SEPTEMBER

Society of Instrument Technology and the British Interplanetary Society, Symposium on Rocket and Satellite Instrumentation, London, England Sept. 1

Production Engineering Show, Navy Pier, Chicago, Ill. Sept. 6-16

National Machine Tool Builders Association, Machine Tool Exposition (in connection with Production Engineering Show), International Amphitheatre, Chicago, Ill. Sept. 6-16

Joint Automatic Control Conference, sponsored by ASME, AIEE, IRE, ISA, and AIChE, Massachusetts Institute of Technology, Cambridge, Mass. Sept. 7-9

Second Coliseum Machinery Show, Chicago Coliseum, Chicago, Ill. Sept. 7-15

International Symposium on Data Transmission, sponsored by IRE, Benelux section, (conducted in English), Technische Hogeschool, Delft, Netherlands Sept. 19-21

Institute of Radio Engineers, National Symposium on Space Electronics and Telemetry, Shoreham Hotel, Washington, D. C. Sept. 19-22

American Institute of Electrical Engineers, Ninth Annual Industrial Electronics Symposium, Sheraton Cleveland Hotel, Cleveland, Ohio Sept. 21-22

Instrument Society of America, 15th Annual Instrument-Automation Conference and Exhibit, New York Coliseum, New York City Sept. 26-30

OCTOBER

American Institute of Electrical Engineers, Fall General Meeting, Morrison Hotel, Chicago, Ill. Oct. 9-14

National Electronics Conference, Hotel Sherman, Chicago, Ill. Oct. 10-12

Institute of Radio Engineers, Symposium on Adaptive Control Systems, Garden City Hotel, Garden City, N. Y. Oct. 17-19

American Society for Metals, 42nd National Metal Exposition and Congress, Trade and Convention Center, Philadelphia, Pa. Oct. 17-21



HOW MUCH DO YOU SPEND AFTER YOUR STRIP CHART RECORDER IS FINISHED???

If your strip chart record must be analyzed after it leaves the recorder, Coleman Electronics can save you money. Here's why—the Coleman DIGITIZER, a shaft encoder, attaches quickly to most strip chart recorders and will furnish *numbers* in any form you require—on a visual display on punched tape, on cards, typed, or machine printed.

Coleman Digitizer Systems make automatic data logging economical for almost anybody.

WRITE FOR INFORMATION, OR PHONE FACULTY 1-4775

Visit Coleman Booth 2306 at WESCON



COLEMAN ELECTRONICS INC.
133 EAST 162ND STREET, GARDENA, CALIFORNIA

CIRCLE 215 ON READER SERVICE CARD

Aboard an Atomic Sub...

PRECISE CONTROL OF TORPEDO FIRING AND MISSILE GUIDANCE OPERATIONS



Atomic Submarine U.S.S. Seadragon

Several STANDARD timers of special design coordinate time between the several operating stations in the "Seadragon's" integrated missile guidance and torpedo fire control system.

Another of Numberless Applications of

SPECIAL TIMERS by STANDARD

What's your need in special timers? For precise process timing . . . accurate test timing . . . precision coordination?

Whatever the application, STANDARD has the engineering skill and experience . . . and the ample production facilities . . . to develop the timer you need.

Accuracies to ±.001 second are available in standard models. Write today requesting descriptive catalog or outlining your special requirements.

Catalog 198A covers the complete line of Standard precision timers . . . portable and panel mounted.

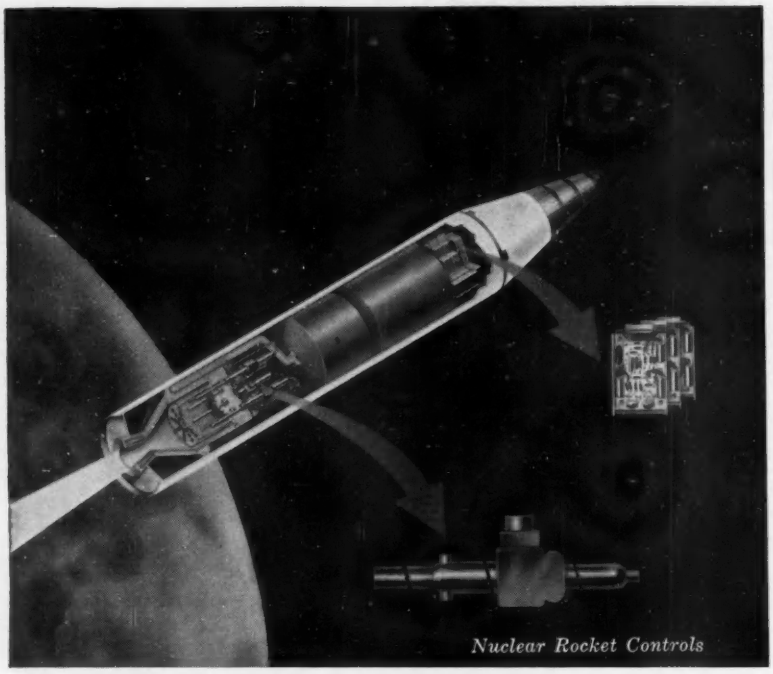


STANDARD Time

THE STANDARD ELECTRIC TIME COMPANY
89 LOGAN STREET • SPRINGFIELD, MASSACHUSETTS

"Splitting the Split Second... Precisely"

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Nuclear Rocket Controls

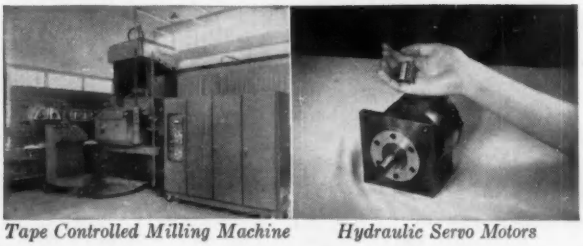
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504—**System Characteristics of Modern Guidance Techniques,** August 1960, 22 pp. In this special report fixe experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—**How to Determine Stream Analyzer Dynamics,** 8 pp. This package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

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501—**Six Transducers for Precision Position Measurement,** May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

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Continued on page 202



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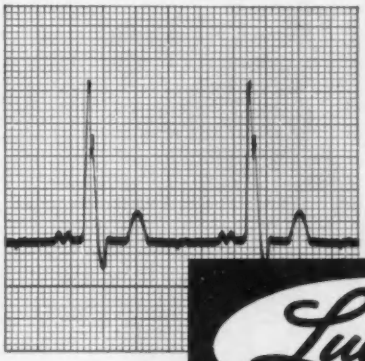
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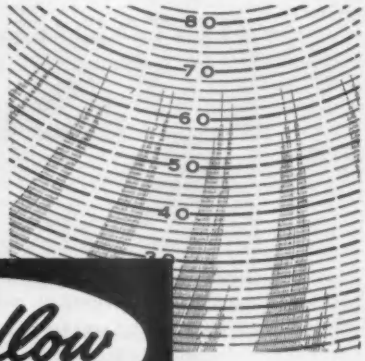
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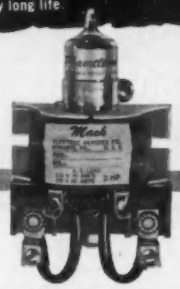
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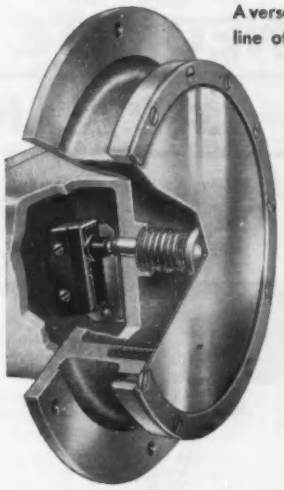
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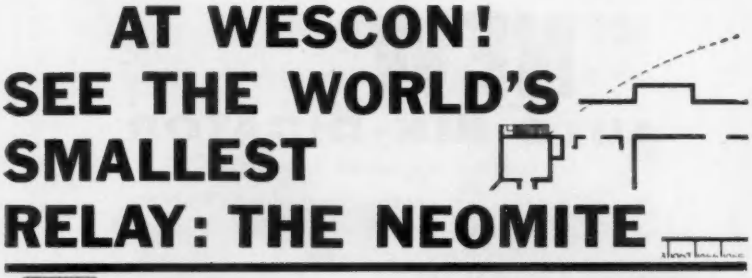
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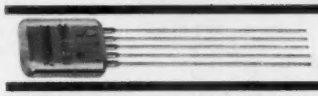
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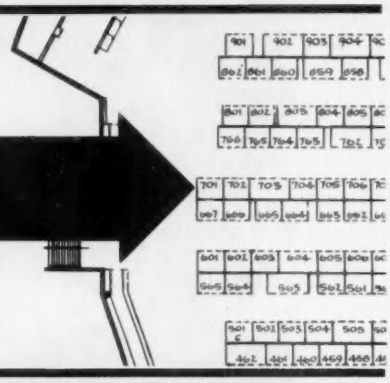
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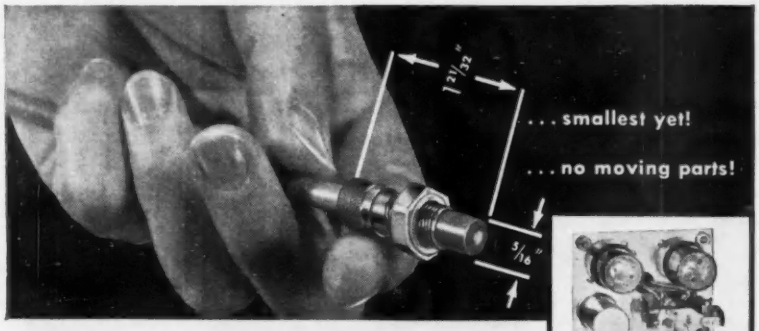
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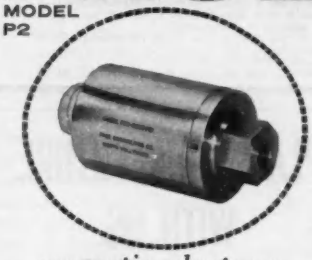
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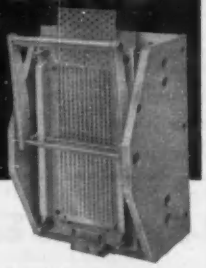
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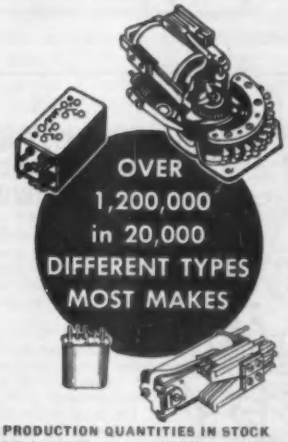
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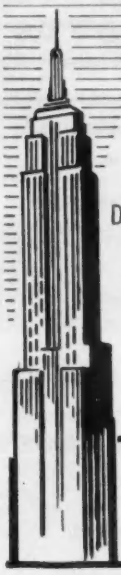
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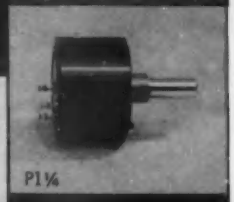
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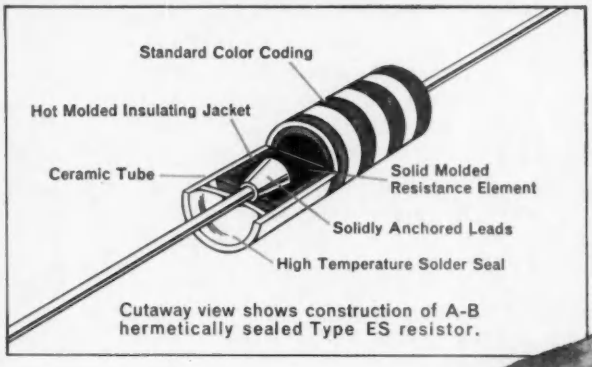
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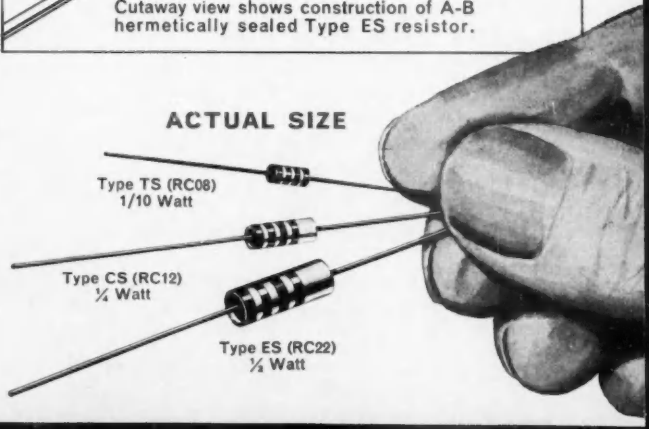
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